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(54) Title: POLYNUCLEOTIDE ENCODING A POLYPEPTIDE HAVING HEPARANASE ACTIVITY AND EXPRESSION OF SAME IN GENETICALLY MODIFIED CELLS

(57) Abstract

A polynucleotide (*hpa*) encoding a polypeptide having heparanase activity, vectors including same, genetically modified cells expressing heparanase, a recombinant protein having heparanase activity and antisense oligonucleotides and constructs for modulating heparanase expression.

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POLYNUCLEOTIDE ENCODING A POLYPEPTIDE HAVING HEPARANASE ACTIVITY AND EXPRESSION OF SAME IN GENETICALLY MODIFIED CELLS

FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to a polynucleotide, referred to hereinbelow as *hpa*, encoding a polypeptide having heparanase activity, vectors (nucleic acid constructs) including same and genetically modified cells expressing heparanase. The invention further relates to a recombinant protein having heparanase activity and to antisense oligonucleotides, constructs and ribozymes for down regulating heparanase activity. In addition, the invention relates to heparanase promoter sequences and their uses.

Heparan sulfate proteoglycans: Heparan sulfate proteoglycans (HSPG) are ubiquitous macromolecules associated with the cell surface and extra cellular matrix (ECM) of a wide range of cells of vertebrate and invertebrate tissues (1-4). The basic HSPG structure includes a protein core to which several linear heparan sulfate chains are covalently attached. These polysaccharide chains are typically composed of repeating hexuronic and D-glucosamine disaccharide units that are substituted to a varying extent with N- and O-linked sulfate moieties and N-linked acetyl groups (1-4). Studies on the involvement of ECM molecules in cell attachment, growth and differentiation revealed a central role of HSPG in embryonic morphogenesis, angiogenesis, neurite outgrowth and tissue repair (1-5). HSPG are prominent components of blood vessels (3). In large blood vessels they are concentrated mostly in the intima and inner media, whereas in capillaries they are found mainly in the subendothelial basement membrane where they support proliferating and migrating endothelial cells and stabilize the structure of the capillary wall. The ability of HSPG to interact with ECM macromolecules such as collagen, laminin and fibronectin, and with different attachment sites on plasma membranes suggests a key role for this proteoglycan in the self-assembly and insolubility of ECM components, as well as in cell adhesion and locomotion. Cleavage of the heparan sulfate (HS) chains may therefore result in degradation of the subendothelial ECM and hence may play a decisive role in extravasation of blood-borne cells. HS catabolism is observed in inflammation, wound repair, diabetes, and cancer metastasis, suggesting that enzymes which degrade HS play important roles in pathologic processes. Heparanase activity has been described in activated

immune system cells and highly metastatic cancer cells (6-8), but research has been handicapped by the lack of biologic tools to explore potential causative roles of heparanase in disease conditions.

Involvement of Heparanase in Tumor Cell Invasion and Metastasis: Circulating tumor cells arrested in the capillary beds of different organs must invade the endothelial cell lining and degrade its underlying basement membrane (BM) in order to invade into the extravascular tissue(s) where they establish metastasis (9, 10). Metastatic tumor cells often attach at or near the intercellular junctions between adjacent endothelial cells. Such attachment of the metastatic cells is followed by rupture of the junctions, retraction of the endothelial cell borders and migration through the breach in the endothelium toward the exposed underlying BM (9). Once located between endothelial cells and the BM, the invading cells must degrade the subendothelial glycoproteins and proteoglycans of the BM in order to migrate out of the vascular compartment. Several cellular enzymes (e.g., collagenase IV, plasminogen activator, cathepsin B, elastase, etc.) are thought to be involved in degradation of BM (10). Among these enzymes is an endo-β-D-glucuronidase (heparanase) that cleaves HS at specific intrachain sites (6, 8, 11). Expression of a HS degrading heparanase was found to correlate with the metastatic potential of mouse lymphoma (11), fibrosarcoma and melanoma (8) cells. Moreover, elevated levels of heparanase were detected in sera from metastatic tumor bearing animals and melanoma patients (8) and in tumor biopsies of cancer patients (12).

The control of cell proliferation and tumor progression by the local microenvironment, focusing on the interaction of cells with the extracellular matrix (ECM) produced by cultured corneal and vascular endothelial cells, was investigated previously by the present inventors. This cultured ECM closely resembles the subendothelium *in vivo* in its morphological appearance and molecular composition. It contains collagens (mostly type III and IV, with smaller amounts of types I and V), proteoglycans (mostly heparan sulfate- and dermatan sulfate- proteoglycans, with smaller amounts of chondroitin sulfate proteoglycans), laminin, fibronectin, entactin and elastin (13, 14). The ability of cells to degrade HS in the cultured ECM was studied by allowing cells to interact with a metabolically sulfate labeled ECM, followed by gel filtration (Sepharose 6B) analysis of degradation products released into the culture medium (11). While intact HSPG are eluted next to the void volume of the column

(Kav<0.2, Mr ~ 0.5×10^6), labeled degradation fragments of HS side chains are eluted more toward the V_t of the column (0.5<kav<0.8, Mr =$5\text{-}7 \times 10^3$) (11).

The heparanase inhibitory effect of various non-anticoagulant species of heparin that might be of potential use in preventing extravasation of blood-borne cells was also investigated by the present inventors. Inhibition of heparanase was best achieved by heparin species containing 16 sugar units or more and having sulfate groups at both the N and O positions. While O-desulfation abolished the heparanase inhibiting effect of heparin, O-sulfated, N-acetylated heparin retained a high inhibitory activity, provided that the N-substituted molecules had a molecular size of about 4,000 daltons or more (7). Treatment of experimental animals with heparanase inhibitors (e.g., non-anticoagulant species of heparin) markedly reduced (>90%) the incidence of lung metastases induced by B16 melanoma, Lewis lung carcinoma and mammary adenocarcinoma cells (7, 8, 16). Heparin fractions with high and low affinity to anti-thrombin III exhibited a comparable high anti-metastatic activity, indicating that the heparanase inhibiting activity of heparin, rather than its anticoagulant activity, plays a role in the anti-metastatic properties of the polysaccharide (7).

Heparanase activity in the urine of cancer patients: In an attempt to further elucidate the involvement of heparanase in tumor progression and its relevance to human cancer, urine samples for heparanase activity were screened (16a). Heparanase activity was detected in the urine of some, but not all, cancer patients. High levels of heparanase activity were determined in the urine of patients with an aggressive metastatic disease and there was no detectable activity in the urine of healthy donors.

Heparanase activity was also found in the urine of 20% of normal and microalbuminuric insulin dependent diabetes mellitus (IDDM) patients, most likely due to diabetic nephropathy, the most important single disorder leading to renal failure in adults.

Possible involvement of heparanase in tumor angiogenesis: Fibroblast growth factors are a family of structurally related polypeptides characterized by high affinity to heparin (17). They are highly mitogenic for vascular endothelial cells and are among the most potent inducers of neovascularization (17, 18). Basic fibroblast growth factor (bFGF) has been extracted from the subendothelial ECM produced *in vitro* (19) and from basement membranes of the cornea (20), suggesting that ECM may serve as

a reservoir for bFGF. Immunohistochemical staining revealed the localization of bFGF in basement membranes of diverse tissues and blood vessels (21). Despite the ubiquitous presence of bFGF in normal tissues, endothelial cell proliferation in these tissues is usually very low, suggesting that bFGF is somehow sequestered from its site of action. Studies on the interaction of bFGF with ECM revealed that bFGF binds to HSPG in the ECM and can be released in an active form by HS degrading enzymes (15, 20, 22). It was demonstrated that heparanase activity expressed by platelets, mast cells, neutrophils, and lymphoma cells is involved in release of active bFGF from ECM and basement membranes (23), suggesting that heparanase activity may not only function in cell migration and invasion, but may also elicit an indirect neovascular response. These results suggest that the ECM HSPG provides a natural storage depot for bFGF and possibly other heparin-binding growth promoting factors (24, 25). Displacement of bFGF from its storage within basement membranes and ECM may therefore provide a novel mechanism for induction of neovascularization in normal and pathological situations.

Recent studies indicate that heparin and HS are involved in binding of bFGF to high affinity cell surface receptors and in bFGF cell signaling (26, 27). Moreover, the size of HS required for optimal effect was similar to that of HS fragments released by heparanase (28). Similar results were obtained with vascular endothelial cells growth factor (VEGF) (29), suggesting the operation of a dual receptor mechanism involving HS in cell interaction with heparin-binding growth factors. It is therefore proposed that restriction of endothelial cell growth factors in ECM prevents their systemic action on the vascular endothelium, thus maintaining a very low rate of endothelial cells turnover and vessel growth. On the other hand, release of bFGF from storage in ECM as a complex with HS fragment, may elicit localized endothelial cell proliferation and neovascularization in processes such as wound healing, inflammation and tumor development (24, 25).

Expression of heparanase by cells of the immune system: Heparanase activity correlates with the ability of activated cells of the immune system to leave the circulation and elicit both inflammatory and autoimmune responses. Interaction of platelets, granulocytes, T and B lymphocytes, macrophages and mast cells with the subendothelial ECM is associated with degradation of HS by a specific heparanase activity (6). The enzyme is released from intracellular compartments (e.g., lysosomes,

specific granules, etc.) in response to various activation signals (e.g., thrombin, calcium ionophore, immune complexes, antigens, mitogens, etc.), suggesting its regulated involvement in inflammation and cellular immunity.

Some of the observations regarding the heparanase enzyme were reviewed in reference No. 6 and are listed hereinbelow:

First, a proteolytic activity (plasminogen activator) and heparanase participate synergistically in sequential degradation of the ECM HSPG by inflammatory leukocytes and malignant cells.

Second, a large proportion of the platelet heparanase exists in a latent form, probably as a complex with chondroitin sulfate. The latent enzyme is activated by tumor cell-derived factor(s) and may then facilitate cell invasion through the vascular endothelium in the process of tumor metastasis.

Third, release of the platelet heparanase from α-granules is induced by a strong stimulant (i.e., thrombin), but not in response to platelet activation on ECM.

Fourth, the neutrophil heparanase is preferentially and readily released in response to a threshold activation and upon incubation of the cells on ECM.

Fifth, contact of neutrophils with ECM inhibited release of noxious enzymes (proteases, lysozyme) and oxygen radicals, but not of enzymes (heparanase, gelatinase) which may enable diapedesis. This protective role of the subendothelial ECM was observed when the cells were stimulated with soluble factors but not with phagocytosable stimulants.

Sixth, intracellular heparanase is secreted within minutes after exposure of T cell lines to specific antigens.

Seventh, mitogens (Con A, LPS) induce synthesis and secretion of heparanase by normal T and B lymphocytes maintained *in vitro*. T lymphocyte heparanase is also induced by immunization with antigen *in vivo*.

Eighth, heparanase activity is expressed by pre-B lymphomas and B-lymphomas, but not by plasmacytomas and resting normal B lymphocytes.

Ninth, heparanase activity is expressed by activated macrophages during incubation with ECM, but there was little or no release of the enzyme into the incubation medium. Similar results were obtained with human myeloid leukemia cells induced to differentiate to mature macrophages.

Tenth, T-cell mediated delayed type hypersensitivity and experimental autoimmunity are suppressed by low doses of heparanase inhibiting non-anticoagulant species of heparin (30).

Eleventh, heparanase activity expressed by platelets, neutrophils and metastatic tumor cells releases active bFGF from ECM and basement membranes. Release of bFGF from storage in ECM may elicit a localized neovascular response in processes such as wound healing, inflammation and tumor development.

Twelfth, among the breakdown products of the ECM generated by heparanase is a tri-sulfated disaccharide that can inhibit T-cell mediated inflammation *in vivo* (31). This inhibition was associated with an inhibitory effect of the disaccharide on the production of biologically active TNFα by activated T cells *in vitro* (31).

Other potential therapeutic applications: Apart from its involvement in tumor cell metastasis, inflammation and autoimmunity, mammalian heparanase may be applied to modulate: bioavailability of heparin-binding growth factors (15); cellular responses to heparin-binding growth factors (e.g., bFGF, VEGF) and cytokines (IL-8) (31a, 29); cell interaction with plasma lipoproteins (32); cellular susceptibility to certain viral and some bacterial and protozoa infections (33, 33a, 33b); and disintegration of amyloid plaques (34). Heparanase may thus prove useful for conditions such as wound healing, angiogenesis, restenosis, atherosclerosis, inflammation, neurodegenerative diseases and viral infections. Mammalian heparanase can be used to neutralize plasma heparin, as a potential replacement of protamine. Anti-heparanase antibodies may be applied for immunodetection and diagnosis of micrometastases, autoimmune lesions and renal failure in biopsy specimens, plasma samples, and body fluids. Common use in basic research is expected.

The identification of the *hpa* gene encoding for heparanase enzyme will enable the production of a recombinant enzyme in heterologous expression systems. Availability of the recombinant protein will pave the way for solving the protein structure function relationship and will provide a tool for developing new inhibitors.

Viral Infection: The presence of heparan sulfate on cell surfaces have been shown to be the principal requirement for the binding of Herpes Simplex (33) and Dengue (33a) viruses to cells and for subsequent infection of the cells. Removal of the cell surface heparan sulfate by heparanase may

therefore abolish virus infection. In fact, treatment of cells with bacterial heparitinase (degrading heparan sulfate) or heparinase (degrading heparan) reduced the binding of two related animal herpes viruses to cells and rendered the cells at least partially resistant to virus infection (33). There are some indications that the cell surface heparan sulfate is also involved in HIV infection (33b).

Neurodegenerative diseases: Heparan sulfate proteoglycans were identified in the prion protein amyloid plaques of Genstmann-Straussler Syndrome, Creutzfeldt-Jakob disease and Scrape (34). Heparanase may disintegrate these amyloid plaques which are also thought to play a role in the pathogenesis of Alzheimer's disease.

Restenosis and Atherosclerosis: Proliferation of arterial smooth muscle cells (SMCs) in response to endothelial injury and accumulation of cholesterol rich lipoproteins are basic events in the pathogenesis of atherosclerosis and restenosis (35). Apart from its involvement in SMC proliferation (i.e., low affinity receptors for heparin-binding growth factors), HS is also involved in lipoprotein binding, retention and uptake (36). It was demonstrated that HSPG and lipoprotein lipase participate in a novel catabolic pathway that may allow substantial cellular and interstitial accumulation of cholesterol rich lipoproteins (32). The latter pathway is expected to be highly atherogenic by promoting accumulation of apoB and apoE rich lipoproteins (i.e. LDL, VLDL, chylomicrons), independent of feed back inhibition by the cellular sterol content. Removal of SMC HS by heparanase is therefore expected to inhibit both SMC proliferation and lipid accumulation and thus may halt the progression of restenosis and atherosclerosis.

Gene therapy:

The ultimate goal in the management of inherited as well as acquired diseases is a rational therapy with the aim to eliminate the underlying biochemical defects associated with the disease rather then symptomatic treatment. Gene therapy is a promising candidate to meet these objectives. Initially it was developed for treatment of genetic disorders, however, the consensus view today is that it offers the prospect of providing therapy for a variety of acquired diseases, including cancer, viral infections, vascular diseases and neurodegenerative disorders.

The gene-based therapeutic can act either intracellularly, affecting only the cells to which it is delivered, or extracellularly, using the recipient cells as local endogenous factories for the therapeutic product(s). The

application of gene therapy may follow any of the following strategies: (i) prophylactic gene therapy, such as using gene transfer to protect cells against viral infection; (ii) cytotoxic gene therapy, such as cancer therapy, where genes encode cytotoxic products to render the target cells vulnerable to attack by the normal immune response; (iii) biochemical correction, primarily for the treatment of single gene defects, where a normal copy of the gene is added to the affected or other cells.

To allow efficient transfer of the therapeutic genes, a variety of gene delivery techniques have been developed based on viral and non-viral vector systems. The most widely used and most efficient systems for delivering genetic material into target cells are viral vectors. So far, 329 clinical studies (phase I, I/II and II) with over 2,500 patients have been initiated Worldwide since 1989 (50).

The approach of gene addition pose serious barriers. The expression of many genes is tightly regulated and context dependent, so achieving the correct balance and function of expression is challenging. The gene itself is often quite large, containing many exons and introns. The delivery vector is usually a virus, which can infect with a high efficiency but may, on the other hand, induce immunological response and consequently decreases effectiveness, especially upon secondary administration. Most of the current expression vector-based gene therapy protocols fail to achieve clinically significant transgene expression required for treating genetic diseases. Apparently, it is difficult to deliver enough virus to the right cell type to elicit an effective and therapeutic effect (51)

Homologous recombination, which was initially considered to be of limited use for gene therapy because of its low frequency in mammalian cells, has recently emerged as a potential strategy for developing gene therapy. Different approaches have been used to study homologous recombination in mammalian cells; some involve DNA repair mechanisms. These studies aimed at either gene disruption or gene correction and include RNA/DNA chimeric oligonucleotides, small or large homologous DNA fragments, or adeno-associated viral vectors. Most of these studies show a reasonable frequency of homologous recombination, which warrants further *in vivo* testing (52). Homologous recombination-based gene therapy has the potential to develop into a powerful therapeutic modality for genetic diseases. It can offer permanent expression and normal regulation of corrected genes in appropriate cells or organs and probably can be used for treating dominantly inherited diseases such as polycystic kidney disease.

Genomic sequences function in regulation of gene expression:

The efficient expression of therapeutic genes in target cells or tissues is an important component of efficient and safe gene therapy. The expression of genes is driven by the promoter region upstream of the coding sequence, although regulation of expression may be supplemented by farther upstream or downstream DNA sequences or DNA in the introns of the gene. Since this important information is embedded in the DNA, the description of gene structure is crucial to the analysis of gene regulation. Characterization of cell specific or tissue specific promoters, as well as other tissue specific regulatory elements enables the use of such sequences to direct efficient cell specific, or developmental stage specific gene expression. This information provides the basis for targeting individual genes and for control of their expression by exogenous agents, such as drugs. Identification of transcription factors and other regulatory proteins required for proper gene expression will point at new potential targets for modulating gene expression, when so desired or required.

Efficient expression of many mammalian genes depends on the presence of at least one intron. The expression of mouse thymidylate synthase (TS) gene, for example, is greatly influenced by intron sequences. The addition of almost any of the introns from the mouse TS gene to an intronless TS minigene leads to a large increase in expression (42). The involvement of intron 1 in the regulation of expression was demonstrated for many other genes. In human factor IX (hFIX), intron 1 is able to increase the expression level about 3 fold mare as compared to that of the hFIX cDNA (43). The expression enhancing activity of intron 1 is due to efficient functional splicing sequences, present in the precursor mRNA. By being efficiently assembled into spliceosome complexes, transcripts with splicing sequences may be better protected in the nucleus from random degradations, than those without such sequences (44).

A forward-inserted intron1-carrying hFIX expression cassette suggested to be useful for directed gene transfer, while for retroviral-mediated gene transfer system, reversely-inserted intron 1-carrying hFIX expression cassette was considered (43).

A highly conserved cis-acting sequence element was identified in the first intron of the mouse and rat c-Ha-ras, and in the first exon of Ha- and Ki-ras genes of human, mouse and rat. This cis-acting regulatory sequence confers strong transcription enhancer activity that is differentially modulated by steroid hormones in metastatic and nonmetastatic

subpopulations. Perturbations in the regulatory activities of such cis-acting sequences may play an important role in governing oncogenic potency of Ha-ras through transcriptional control mechanisms (45).

Intron sequences affect tissue specific, as well as inducible gene expression. A 182 bp intron 1 DNA segment of the mouse Col2a1 gene contains the necessary information to confer high-level, temporally correct, chondrocyte expression on a reporter gene in intact mouse embryos, while Col2a1 promoter sequences are dispensable for chondrocyte expression (46). In Col1A1 gene the intron plays little or no role in constitutive expression of collagen in the skin, and in cultured cells derived from the skin, however, in the lungs of young mice, intron deletion results in decrease of expression to less than 50 % (47).

A classical enhancer activity was shown in the 2 kb intron fragment in bovine beta-casein gene. The enhancer activity was largely dependent on the lactogenic hormones, especially prolactin. It was suggested that several elements in the intron-1 of the bovine beta-casein gene cooperatively interact not only with each other but also with its promoter for hormonal induction (48).

Identification and characterization of regulatory elements in genomic non-coding sequences, such as introns, provides a tool for designing and constructing novel vectors for tissue specific, hormone regulated or any other defined expression pattern, for gene therapy. Such an expression cassette was developed, utilizing regulatory elements from the human cytokeratin 18 (K18) gene, including 5' genomic sequences and one of its introns. This cassette efficiently expresses reporter genes, as well as the human cystic fibrosis transmembrane conductance regulator (CFTR) gene, in cultured lung epithelial cells (49).

Alternative splicing:

Alternative splicing of pre mRNA is a powerful and versatile regulatory mechanism that can effect quantitative control of gene expression and functional diversification of proteins. It contributes to major developmental decisions and also to a fine-tuning of gene function. Genetic and biochemical approaches have identified cis-acting regulatory elements and trans-acting factors that control alternative splicing of specific mRNAs. This mechanism results in the generation of variant isoforms of various proteins from a single gene. These include cell surface molecules such as CD44, receptors, cytokines such as VEGF and enzymes. Products of

alternatively spliced transcripts differ in their expression pattern, substrate specificity and other biological parameters.

The FGF receptor RNA undergoes alternative splicing which results in the production of several isoforms, which exhibit different ligand binding specificities. The alternative splicing is regulated in a cell specific manner (53).

Alternative spliced mRNAs are often correlated with malignancy. An increase in specific splice variant of tyrosinase was identified in murine melanomas (54). Multiple splicing variants of estrogen receptor are present in individual human breast tumors. CD44 has various isoform, some are characteristic of malignant tissues.

Identification of tumor specific alternative splice variants provide new tool for cancer diagnostics. CD44 variants have been used for detection of malignancy in urine samples from patients with urothelial cancer by competitive RT-PCR (55). CD44 exon 6 was suggested as prognostic indicator of metastasis in breast cancer (56).

Different enzymes or polypeptides generated by alternative splicing may have different function or catalytic specificity. The identification and characterization of the enzyme forms, which are involved in pathological processes, is crucial for the design of appropriate and efficient drugs.

Modulation of gene expression – Antisense technology:

An antisense oligonucleotide (e.g., antisense oligodeoxyribonucleotide) may bind its target nucleic acid either by Watson-Crick base pairing or Hoogsteen and anti-Hoogsteen base pairing (64). According to the Watson-Crick base pairing, heterocyclic bases of the antisense oligonucleotide form hydrogen bonds with the heterocyclic bases of target single-stranded nucleic acids (RNA or single-stranded DNA), whereas according to the Hoogsteen base pairing, the heterocyclic bases of the target nucleic acid are double-stranded DNA, wherein a third strand is accommodated in the major groove of the B-form DNA duplex by Hoogsteen and anti-Hoogsteen base pairing to form a triple helix structure.

According to both the Watson-Crick and the Hoogsteen base pairing models, antisense oligonucleotides have the potential to regulate gene expression and to disrupt the essential functions of the nucleic acids in cells. Therefore, antisense oligonucleotides have possible uses in modulating a wide range of diseases in which gene expression is altered.

Since the development of effective methods for chemically synthesizing oligonucleotides, these molecules have been extensively used

in biochemistry and biological research and have the potential use in medicine, since carefully devised oligonucleotides can be used to control gene expression by regulating levels of transcription, transcripts and/or translation.

Oligodeoxyribonucleotides as long as 100 base pairs (bp) are routinely synthesized by solid phase methods using commercially available, fully automated synthesis machines. The chemical synthesis of oligoribonucleotides, however, is far less routine. Oligoribonucleotides are also much less stable than oligodeoxyribonucleotides, a fact which has contributed to the more prevalent use of oligodeoxyribonucleotides in medical and biological research, directed at, for example, the regulation of transcription or translation levels.

Gene expression involves few distinct and well regulated steps. The first major step of gene expression involves transcription of a messenger RNA (mRNA) which is an RNA sequence complementary to the antisense (i.e., -) DNA strand, or, in other words, identical in sequence to the DNA sense (i.e., +) strand, composing the gene. In eukaryotes, transcription occurs in the cell nucleus.

The second major step of gene expression involves translation of a protein (e.g., enzymes, structural proteins, secreted proteins, gene expression factors, etc.) in which the mRNA interacts with ribosomal RNA complexes (ribosomes) and amino acid activated transfer RNAs (tRNAs) to direct the synthesis of the protein coded for by the mRNA sequence.

Initiation of transcription requires specific recognition of a promoter DNA sequence located upstream to the coding sequence of a gene by an RNA-synthesizing enzyme -- RNA polymerase. This recognition is preceded by sequence-specific binding of one or more transcription factors to the promoter sequence. Additional proteins which bind at or close to the promoter sequence may trans upregulate transcription via cis elements known as enhancer sequences. Other proteins which bind to or close to the promoter, but whose binding prohibits the action of RNA polymerase, are known as repressors.

There are also evidence that in some cases gene expression is downregulated by endogenous antisense RNA repressors that bind a complementary mRNA transcript and thereby prevent its translation into a functional protein.

Thus, gene expression is typically upregulated by transcription factors and enhancers and downregulated by repressors.

However, in many disease situation gene expression is impaired. In many cases, such as different types of cancer, for various reasons the expression of a specific endogenous or exogenous (e.g., of a pathogen such as a virus) gene is upregulated. Furthermore, in infectious diseases caused by pathogens such as parasites, bacteria or viruses, the disease progression depends on expression of the pathogen genes, this phenomenon may also be considered as far as the patient is concerned as upregulation of exogenous genes.

Most conventional drugs function by interaction with and modulation of one or more targeted endogenous or exogenous proteins, e.g., enzymes. Such drugs, however, typically are not specific for targeted proteins but interact with other proteins as well. Thus, a relatively large dose of drug must be used to effectively modulate a targeted protein.

Typical daily doses of drugs are from 10^{-5} - 10^{-1} millimoles per kilogram of body weight or 10^{-3} - 10 millimoles for a 100 kilogram person. If this modulation instead could be effected by interaction with and inactivation of mRNA, a dramatic reduction in the necessary amount of drug could likely be achieved, along with a corresponding reduction in side effects. Further reductions could be effected if such interaction could be rendered site-specific. Given that a functioning gene continually produces mRNA, it would thus be even more advantageous if gene transcription could be arrested in its entirety.

Given these facts, it would be advantageous if gene expression could be arrested or downmodulated at the transcription level.

The ability of chemically synthesizing oligonucleotides and analogs thereof having a selected predetermined sequence offers means for downmodulating gene expression. Three types of gene expression modulation strategies may be considered.

At the transcription level, antisense or sense oligonucleotides or analogs that bind to the genomic DNA by strand displacement or the formation of a triple helix, may prevent transcription (64).

At the transcript level, antisense oligonucleotides or analogs that bind target mRNA molecules lead to the enzymatic cleavage of the hybrid by intracellular RNase H (65). In this case, by hybridizing to the targeted mRNA, the oligonucleotides or oligonucleotide analogs provide a duplex hybrid recognized and destroyed by the RNase H enzyme. Alternatively, such hybrid formation may lead to interference with correct splicing (66).

As a result, in both cases, the number of the target mRNA intact transcripts ready for translation is reduced or eliminated.

At the translation level, antisense oligonucleotides or analogs that bind target mRNA molecules prevent, by steric hindrance, binding of essential translation factors (ribosomes), to the target mRNA, a phenomenon known in the art as hybridization arrest, disabling the translation of such mRNAs (67).

Thus, antisense sequences, which as described hereinabove may arrest the expression of any endogenous and/or exogenous gene depending on their specific sequence, attracted much attention by scientists and pharmacologists who were devoted at developing the antisense approach into a new pharmacological tool (68).

For example, several antisense oligonucleotides have been shown to arrest hematopoietic cell proliferation (69), growth (70), entry into the S phase of the cell cycle (71), reduced survival (72) and prevent receptor mediated responses (73). For use of antisense oligonucleotides as antiviral agents the reader is referred to reference 74.

For efficient *in vivo* inhibition of gene expression using antisense oligonucleotides or analogs, the oligonucleotides or analogs must fulfill the following requirements (i) sufficient specificity in binding to the target sequence; (ii) solubility in water; (iii) stability against intra- and extracellular nucleases; (iv) capability of penetration through the cell membrane; and (v) when used to treat an organism, low toxicity.

Unmodified oligonucleotides are impractical for use as antisense sequences since they have short *in vivo* half-lives, during which they are degraded rapidly by nucleases. Furthermore, they are difficult to prepare in more than milligram quantities. In addition, such oligonucleotides are poor cell membrane penetraters (75).

Thus it is apparent that in order to meet all the above listed requirements, oligonucleotide analogs need to be devised in a suitable manner. Therefore, an extensive search for modified oligonucleotides has been initiated.

For example, problems arising in connection with double-stranded DNA (dsDNA) recognition through triple helix formation have been diminished by a clever "switch back" chemical linking, whereby a sequence of polypurine on one strand is recognized, and by "switching back", a homopurine sequence on the other strand can be recognized. Also, good

helix formation has been obtained by using artificial bases, thereby improving binding conditions with regard to ionic strength and pH.

In addition, in order to improve half-life as well as membrane penetration, a large number of variations in polynucleotide backbones have been done, nevertheless with little success.

Oligonucleotides can be modified either in the base, the sugar or the phosphate moiety. These modifications include, for example, the use of methylphosphonates, monothiophosphates, dithiophosphates, phosphoramidates, phosphate esters, bridged phosphorothioates, bridged phosphoramidates, bridged methylenephosphonates, dephospho internucleotide analogs with siloxane bridges, carbonate bridges, carboxymethyl ester bridges, carbonate bridges, carboxymethyl ester bridges, acetamide bridges, carbamate bridges, thioether bridges, sulfoxy bridges, sulfono bridges, various "plastic" DNAs, α-anomeric bridges and borane derivatives. For further details the reader is referred to reference 76.

International patent application WO 89/12060 discloses various building blocks for synthesizing oligonucleotide analogs, as well as oligonucleotide analogs formed by joining such building blocks in a defined sequence. The building blocks may be either "rigid" (i.e., containing a ring structure) or "flexible" (i.e., lacking a ring structure). In both cases, the building blocks contain a hydroxy group and a mercapto group, through which the building blocks are said to join to form oligonucleotide analogs. The linking moiety in the oligonucleotide analogs is selected from the group consisting of sulfide (-S-), sulfoxide (-SO-), and sulfone ($-SO_2-$). However, the application provides no data supporting the specific binding of an oligonucleotide analog to a target oligonucleotide.

International patent application WO 92/20702 describe an acyclic oligonucleotide which includes a peptide backbone on which any selected chemical nucleobases or analogs are stringed and serve as coding characters as they do in natural DNA or RNA. These new compounds, known as peptide nucleic acids (PNAs), are not only more stable in cells than their natural counterparts, but also bind natural DNA and RNA 50 to 100 times more tightly than the natural nucleic acids cling to each other (77). PNA oligomers can be synthesized from the four protected monomers containing thymine, cytosine, adenine and guanine by Merrifield solid-phase peptide synthesis. In order to increase solubility in water and to prevent aggregation, a lysine amide group is placed at the C-terminal.

Thus, antisense technology requires pairing of messenger RNA with an oligonucleotide to form a double helix that inhibits translation. The concept of antisense-mediated gene therapy was already introduced in 1978 for cancer therapy. This approach was based on certain genes that are crucial in cell division and growth of cancer cells. Synthetic fragments of genetic substance DNA can achieve this goal. Such molecules bind to the targeted gene molecules in RNA of tumor cells, thereby inhibiting the translation of the genes and resulting in dysfunctional growth of these cells. Other mechanisms has also been proposed. These strategies have been used, with some success in treatment of cancers, as well as other illnesses, including viral and other infectious diseases. Antisense oligonucleotides are typically synthesized in lengths of 13-30 nucleotides. The life span of oligonucleotide molecules in blood is rather short. Thus, they have to be chemically modified to prevent destruction by ubiquitous nucleases present in the body. Phosphorothioates are very widely used modification in antisense oligonucleotide ongoing clinical trials (57). A new generation of antisense molecules consist of hybrid antisense oligonucleotide with a central portion of synthetic DNA while four bases on each end have been modified with 2'O-methyl ribose to resemble RNA. In preclinical studies in laboratory animals, such compounds have demonstrated greater stability to metabolism in body tissues and an improved safety profile when compared with the first-generation unmodified phosphorothioate (Hybridon Inc. news). Dosens of other nucleotide analogs have also been tested in antisense technology.

RNA oligonucleotides may also be used for antisense inhibition as they form a stable RNA-RNA duplex with the target, suggesting efficient inhibition. However, due to their low stability RNA oligonucleotides are typically expressed inside the cells using vectors designed for this purpose. This approach is favored when attempting to target a mRNA that encodes an abundant and long-lived protein (57).

Recent scientific publications have validated the efficacy of antisense compounds in animal models of hepatitis, cancers, coronary artery restenosis and other diseases. The first antisense drug was recently approved by the FDA. This drug Fomivirsen, developed by Isis, is indicated for local treatment of cytomegalovirus in patients with AIDS who are intolerant of or have a contraindication to other treatments for CMV retinitis or who were insufficiently responsive to previous treatments for CMV retinitis (Pharmacotherapy News Network).

Several antisense compounds are now in clinical trials in the United States. These include locally administered antivirals, systemic cancer therapeutics. Antisense therapeutics has the potential to treat many life-threatening diseases with a number of advantages over traditional drugs. Traditional drugs intervene after a disease-causing protein is formed. Antisense therapeutics, however, block mRNA transcription/translation and intervene before a protein is formed, and since antisense therapeutics target only one specific mRNA, they should be more effective with fewer side effects than current protein-inhibiting therapy.

A second option for disrupting gene expression at the level of transcription uses synthetic oligonucleotides capable of hybridizing with double stranded DNA. A triple helix is formed. Such oligonucleotides may prevent binding of transcription factors to the gene's promoter and therefore inhibit transcription. Alternatively, they may prevent duplex unwinding and, therefore, transcription of genes within the triple helical structure.

Another approach is the use of specific nucleic acid sequences to act as decoys for transcription factors. Since transcription factors bind specific DNA sequences it is possible to synthesize oligonucleotides that will effectively compete with the native DNA sequences for available transcription factors *in vivo*. This approach requires the identification of gene specific transcription factor (57).

Indirect inhibition of gene expression was demonstrated for matrix metalloproteinase genes (MMP-1, -3, and -9), which are associated with invasive potential of human cancer cells. E1AF is a transcription activator of MMP genes. Expression of E1AF antisense RNA in HSC3AS cells showed decrease in mRNA and protein levels of MMP-1, -3, and -9. Moreover, HSC3AS showed lower invasive potential in vitro and *in vivo*. These results imply that transfection of antisense inhibits tumor invasion by down-regulating MMP genes (58).

Ribozymes:

Ribozymes are being increasingly used for the sequence-specific inhibition of gene expression by the cleavage of mRNAs encoding proteins of interest. The possibility of designing ribozymes to cleave any specific target RNA has rendered them valuable tools in both basic research and therapeutic applications. In the therapeutics area, ribozymes have been exploited to target viral RNAs in infectious diseases, dominant oncogenes in cancers and specific somatic mutations in genetic disorders. Most notably, several ribozyme gene therapy protocols for HIV patients are

already in Phase 1 trials (62). More recently, ribozymes have been used for transgenic animal research, gene target validation and pathway elucidation. Several ribozymes are in various stages of clinical trials. ANGIOZYME was the first chemically synthesized ribozyme to be studied in human clinical trials. ANGIOZYME specifically inhibits formation of the VEGF-r (Vascular Endothelial Growth Factor receptor), a key component in the angiogenesis pathway. Ribozyme Pharmaceuticals, Inc., as well as other firms have demonstrated the importance of anti-angiogenesis therapeutics in animal models. HEPTAZYME, a ribozyme designed to selectively destroy Hepatitis C Virus (HCV) RNA, was found effective in decreasing Hepatitis C viral RNA in cell culture assays (Ribozyme Pharmaceuticals, Incorporated - WEB home page).

Gene disruption in animal models:

The emergence of gene inactivation by homologous recombination methodology in embryonic stem cells has revolutionized the field of mouse genetics. The availability of a rapidly growing number of mouse null mutants has represented an invaluable source of knowledge on mammalian development, cellular biology and physiology, and has provided many models for human inherited diseases. Animal models are required for an effective drug delivery development program and evaluation of gene therapy approach. The improvement of the original knockout strategy, as well as exploitation of exogenous enzymatic systems that are active in the recombination process, has been considerably extended the range of genetic manipulations that can be produced. Additional methods have been developed to provide versatile research tools: Double replacement method, sequential gene targeting, conditional cell type specific gene targeting, single copy integration method, inducible gene targeting, gene disruption by viral delivery, replacing one gene with another, the so called knock-in method and the induction of specific balanced chromosomal translocation. It is now possible to introduce a point mutation as a unique change in the entire genome, therefore allowing very fine dissection of gene function *in vivo*. Furthermore, the advent of methods allowing conditional gene targeting opens the way for analysis of consequence of a particular mutation in a defined organ and at a specific time during the life of the experimental animal (59).

DNA vaccination:

Observations in the early 1990s that plasmid DNA could directly transfect animal cells *in vivo* sparked exploration of the use of DNA

plasmids to induce immune response by direct injection into animal of DNA encoding antigenic protein. When a DNA vaccine plasmid enters the eukaryotic cell, the protein it encodes is transcribed and translated within the cell. In the case of pathogens, these proteins are presented to the immune system in their native form, mimicking the presentation of antigens during a natural infection. DNA vaccination is particularly useful for the induction of T cell activation. It was applied for viral and bacterial infectious diseases, as well as for allergy and for cancer. The central hypothesis behind active specific immunotherapy for cancer is that tumor cells express unique antigens that should stimulate the immune system. The first DNA vaccine against tumor was carcino-embrionic antigen (CEA). DNA vaccinated animals expressed immunoprotection and immunotherapy of human CEA-expressing syngeneic mouse colon and breast carcinoma (61). In a mouse model of neuroblastoma, DNA immunization with HuD resulted in tumor growth inhibition with no neurological disease (60). Immunity to the brown locus protein, gp^{75} tyrosinase-related protein-1, associated with melanoma, was investigated in a syngeneic mouse model. Priming with human gp75 DNA broke tolerance to mouse gp75. Immunity against mouse gp75 provided significant tumor protection (60).

Glycosyl hydrolases:

Glycosyl hydrolases are a widespread group of enzymes that hydrolyze the o-glycosidic bond between two or more carbohydrates or between a carbohydrate and a noncarbohydrate moiety. The enzymatic hydrolysis of glycosidic bond occurs by using major one or two mechanisms leading to overall retention or inversion of the anomeric configuration. In both mechanisms catalysis involves two residues: a proton donor and a nucleophile. Glycosyl hydrolyses have been classified into 58 families based on amino acid similarities. The glycosyl hydrolyses from families 1, 2, 5, 10, 17, 30, 35, 39 and 42 act on a large variety of substrates, however, they all hydrolyze the glycosidic bond in a general acid catalysis mechanism, with retention of the anomeric configuration. The mechanism involves two glutamic acid residues, which are the proton donors and the nucleophile, with an aspargine always preceding the proton donor. Analyses of a set of known 3D structures from this group revealed that their catalytic domains, despite the low level of sequence identity, adopt a similar (α/β) 8 fold with the proton donor and the nucleophile located at the C-terminal ends of strands β4 and β7, respectively. Mutations

in the functional conserved amino acids of lysosomal glycosyl hydrolases were identified in lysosomal storage diseases.

Lysosomal glycosyl hydrolases including β-glucuronidase, β-manosidase, β-glucocerebrosidase, β-galactosidase and α-L iduronidase, are all exo-glycosyl hydrolases, belong to the GH-A clan and share a similar catalytic site. However, many endo-glucanases from various organisms, such as bacterial and fungal xylenases and cellulases share this catalytic domain.

Genomic sequence of hpa gene and its implications:

It is well established that heparanase activity is correlated with cancer metastasis. This correlation was demonstrated at the level of enzymatic activity as well as the levels of protein and *hpa* cDNA expression in highly metastatic cancer cells as compared with non-metastatic cells. As such, inhibition of heparanase activity is desirable, and has been attempted by several means. The genomic region, encoding the *hpa* gene and the surrounding, provides a new powerful tool for regulation of heparanase activity at the level of gene expression. Regulatory sequences may reside in noncoding regions both upstream and downstream the transcribed region as well as in intron sequences. A DNA sequence upstream of the transcription start site contains the promoter region and potential regulatory elements. Regulatory factors, which interact with the promoter region may be identified and be used as potential drugs for inhibition of cancer, metastasis and inflammation. The promoter region can be used to screen for inhibitors of heparanase gene expression. Furthermore, the *hpa* promoter can be used to direct cell specific, particularly cancer cell specific, expression of foreign genes, such as cytotoxic or apoptotic genes, in order to specifically destroy cancer cells.

Cancer and yet unknown related genetic disorders may involve rearrangements and mutations in the heparanase gene, either in coding or non-coding regions. Such mutations may affect expression level or enzymatic activity. The genomic sequence of *hpa* enables the amplification of specific genomic DNA fragments, identification and diagnosis of mutations.

There is thus a widely recognized need for, and it would be highly advantageous to have genomic, cDNA and composite polynucleotides encoding a polypeptide having heparanase activity, vectors including same, genetically modified cells expressing heparanase and a recombinant protein

having heparanase activity, as well as antisense oligonucleotides, constructs and ribozymes which can be used for down regulation heparanase activity.

SUMMARY OF THE INVENTION

Cloning of the human *hpa* gene which encodes heparanase, and expression of recombinant heparanase by transfected host cells is reported herein, as well as downregulation of heparanase activity by antisense technology.

A purified preparation of heparanase isolated from human hepatoma cells was subjected to tryptic digestion and microsequencing. The YGPDVGQPR (SEQ ID NO:8) sequence revealed was used to screen EST databases for homology to the corresponding back translated DNA sequence. Two closely related EST sequences were identified and were thereafter found to be identical. Both clones contained an insert of 1020 bp which included an open reading frame of 973 bp followed by a 27 bp of 3' untranslated region and a Poly A tail. Translation start site was not identified.

Cloning of the missing 5' end of *hpa* was performed by PCR amplification of DNA from placenta Marathon RACE cDNA composite using primers selected according to the EST clones sequence and the linkers of the composite. A 900 bp PCR fragment, partially overlapping with the identified 3' encoding EST clones was obtained. The joined cDNA fragment (*hpa*), 1721 bp long (SEQ ID NO:9), contained an open reading frame which encodes a polypeptide of 543 amino acids (SEQ ID NO:10) with a calculated molecular weight of 61,192 daltons.

Cloning an extended 5' sequence was enabled from the human SK-hep1 cell line by PCR amplification using the Marathon RACE. The 5' extended sequence of the SK-hep1 *hpa* cDNA was assembled with the sequence of the *hpa* cDNA isolated from human placenta (SEQ ID NO:9). The assembled sequence contained an open reading frame, SEQ ID NOs: 13 and 15, which encodes, as shown in SEQ ID NOs:14 and 15, a polypeptide of 592 amino acids with a calculated molecular weight of 66,407 daltons.

The ability of the *hpa* gene product to catalyze degradation of heparan sulfate in an *in vitro* assay was examined by expressing the entire open reading frame of *hpa* in insect cells, using the Baculovirus expression system. Extracts and conditioned media of cells infected with virus containing the *hpa* gene, demonstrated a high level of heparan sulfate degradation activity both towards soluble ECM-derived HSPG and intact

ECM. This degradation activity was inhibited by heparin, which is another substrate of heparanase. Cells infected with a similar construct containing no *hpa* gene had no such activity, nor did non-infected cells. The ability of heparanase expressed from the extended 5' clone towards heparin was demonstrated in a mammalian expression system.

The expression pattern of *hpa* RNA in various tissues and cell lines was investigated using RT-PCR. It was found to be expressed only in tissues and cells previously known to have heparanase activity.

A panel of monochromosomal human/CHO and human/mouse somatic cell hybrids was used to localize the human heparanase gene to human chromosome 4. The newly isolated heparanase sequence can be used to identify a chromosome region harboring a human heparanase gene in a chromosome spread.

A human genomic library was screened and the human locus harboring the heparanase gene isolated, sequenced and characterized. Alternatively spliced heparanase mRNAs were identified and characterized. The human heparanase promoter has been isolated, identified and positively tested for activity. The mouse heparanase promoter has been isolated and identified as well. Antisense heparanase constructs were prepared and their influence on cells *in vitro* tested. A predicted heparanase active site was identified. And finally, the presence of sequences hybridizing with human heparanase sequences was demonstrated for a variety of mammalians and for an avian.

According to one aspect of the present invention there is provided an isolated nucleic acid comprising a genomic, complementary or composite polynucleotide sequence encoding a polypeptide having heparanase catalytic activity.

According to further features in preferred embodiments of the invention described below, the polynucleotide or a portion thereof is hybridizable with SEQ ID NOs: 9, 13, 42, 43 or a portion thereof at 68 °C in 6 x SSC, 1 % SDS, 5 x Denharts, 10 % dextran sulfate, 100 μg/ml salmon sperm DNA, and ^{32}p labeled probe and wash at 68 °C with 3 x SSC and 0.1 % SDS.

According to still further features in the described preferred embodiments the polynucleotide or a portion thereof is at least 60 % identical with SEQ ID NOs: 9, 13, 42, 43 or portions thereof as determined using the Bestfit procedure of the DNA sequence analysis software package

developed by the Genetic Computer Group (GCG) at the university of Wisconsin (gap creation penalty - 12, gap extension penalty - 4).

According to still further features in the described preferred embodiments the polypeptide is as set forth in SEQ ID NOs:10, 14, 44 or portions thereof.

According to still further features in the described preferred embodiments the polypeptide is at least 60 % homologous to SEQ ID NOs:10, 14, 44 or portions thereof as determined with the Smith-Waterman algorithm, using the Bioaccelerator platform developed by Compugene (gapop: 10.0, gapext: 0.5, matrix: blosum62).

According to additional aspects of the present invention there are provided a nucleic acid construct (vector) comprising the isolated nucleic acid described herein and a host cell comprising the construct.

According to a further aspect of the present invention there is provided an antisense oligonucleotide comprising a polynucleotide or a polynucleotide analog of at least 10 bases being hybridizable *in vivo*, under physiological conditions, with a portion of a polynucleotide strand encoding a polypeptide having heparanase catalytic activity.

According to an additional aspect of the present invention there is provided a method of *in vivo* downregulating heparanase activity comprising the step of *in vivo* administering the antisense oligonucleotide herein described.

According to yet an additional aspect of the present invention there is provided a pharmaceutical composition comprising the antisense oligonucleotide herein described and a pharmaceutically acceptable carrier.

According to still an additional aspect of the present invention there is provided a ribozyme comprising the antisense oligonucleotide described herein and a ribozyme sequence.

According to a further aspect of the present invention there is provided an antisense nucleic acid construct comprising a promoter sequence and a polynucleotide sequence directing the synthesis of an antisense RNA sequence of at least 10 bases being hybridizable *in vivo*, under physiological conditions, with a portion of a polynucleotide strand encoding a polypeptide having heparanase catalytic activity.

According to further features in preferred embodiments of the invention described below, the polynucleotide strand encoding the polypeptide having heparanase catalytic activity is as set forth in SEQ ID NOs: 9, 13, 42 or 43.

According to still further features in the described preferred embodiments the polypeptide having heparanase catalytic activity is as set forth in SEQ ID NOs: 10, 14 or 44.

According to still a further aspect of the present invention there is provided a method of *in vivo* downregulating heparanase activity comprising the step of *in vivo* administering the antisense nucleic acid construct herein described.

According to yet a further aspect of the present invention there is provided a pharmaceutical composition comprising the antisense nucleic acid construct herein described and a pharmaceutically acceptable carrier.

According to a further aspect of the present invention there is provided a nucleic acid construct comprising a polynucleotide sequence functioning as a promoter, the polynucleotide sequence is derived from SEQ ID NO:42 and includes at least nucleotides 2535-2635 thereof or from SEQ ID NO:43 and includes at least nucleotides 320-420.

According to a further aspect of the present invention there is provided a method of expressing a polynucleotide sequence comprising the step of ligating the polynucleotide sequence into the nucleic acid construct described above, downstream of the polynucleotide sequence derived from SEQ ID NOs:42 or 43.

According to a further aspect of the present invention there is provided a recombinant protein comprising a polypeptide having heparanase catalytic activity.

According to further features in preferred embodiments of the invention described below, the polypeptide includes at least a portion of SEQ ID NOs:10, 14 or 44.

According to still further features in the described preferred embodiments the protein is encoded by a polynucleotide hybridizable with SEQ ID NOs: 9, 13, 42, 43 or a portion thereof at 68 °C in 6 x SSC, 1 % SDS, 5 x Denharts, 10 % dextran sulfate, 100 μg/ml salmon sperm DNA, and ^{32}p labeled probe and wash at 68 °C with 3 x SSC and 0.1 % SDS.

According to still further features in the described preferred embodiments the protein is encoded by a polynucleotide at least 60 % identical with SEQ ID NOs: 9, 13, 42, 43 or portions thereof as determined using the Bestfit procedure of the DNA sequence analysis software package developed by the Genetic Computer Group (GCG) at the university of Wisconsin (gap creation penalty - 12, gap extension penalty - 4).

According to a further aspect of the present invention there is provided a pharmaceutical composition comprising, as an active ingredient, the recombinant protein herein described.

According to a further aspect of the present invention there is provided a method of identifying a chromosome region harboring a heparanase gene in a chromosome spread comprising the steps of (a) hybridizing the chromosome spread with a tagged polynucleotide probe encoding heparanase; (b) washing the chromosome spread, thereby removing excess of non-hybridized probe; and (c) searching for signals associated with the hybridized tagged polynucleotide probe, wherein detected signals being indicative of a chromosome region harboring a heparanase gene.

According to a further aspect of the present invention there is provided a method of *in vivo* eliciting anti-heparanase antibodies comprising the steps of administering a nucleic acid construct including a polynucleotide segment corresponding to at least a portion of SEQ ID NOs:9, 13 or 43 and a promoter for directing the expression of said polynucleotide segment *in vivo*. Accordingly, there is provided also a DNA vaccine for *in vivo* eliciting anti-heparanase antibodies comprising a nucleic acid construct including a polynucleotide segment corresponding to at least a portion of SEQ ID NOs:9, 13 or 43 and a promoter for directing the expression of said polynucleotide segment *in vivo*.

The present invention can be used to develop new drugs to inhibit tumor cell metastasis, inflammation and autoimmunity. The identification of the *hpa* gene encoding for heparanase enzyme enables the production of a recombinant enzyme in heterologous expression systems. Additional features, advantages, uses and applications of the present invention in biological science and in diagnostic and therapeutic medicine are described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention herein described, by way of example only, with reference to the accompanying drawings, wherein:

FIG. 1 presents nucleotide sequence and deduced amino acid sequence of *hpa* cDNA. A single nucleotide difference at position 799 (A to T) between the EST (Expressed Sequence Tag) and the PCR amplified cDNA (reverse transcribed RNA) and the resulting amino acid substitution (Tyr to Phe) are indicated above and below the substituted unit,

respectively. Cysteine residues and the poly adenylation consensus sequence are underlined. The asterisk denotes the stop codon TGA.

FIG. 2 demonstrates degradation of soluble sulfate labeled HSPG substrate by lysates of High Five cells infected with pF*hpa*2 virus. Lysates of High Five cells that were infected with pF*hpa*2 virus (•) or control pF2 virus (□) were incubated (18 h, 37 °C) with sulfate labeled ECM-derived soluble HSPG (peak I). The incubation medium was then subjected to gel filtration on Sepharose 6B. Low molecular weight HS degradation fragments (peak II) were produced only during incubation with the pF*hpa*2 infected cells, but there was no degradation of the HSPG substrate (◇) by lysates of pF2 infected cells.

FIGs. 3a-b demonstrate degradation of soluble sulfate labeled HSPG substrate by the culture medium of pF*hpa*2 and pF*hpa*4 infected cells. Culture media of High Five cells infected with pF*hpa*2 (3a) or pF*hpa*4 (3b) viruses (•), or with control viruses (□) were incubated (18 h, 37 °C) with sulfate labeled ECM-derived soluble HSPG (peak I, ◇). The incubation media were then subjected to gel filtration on Sepharose 6B. Low molecular weight HS degradation fragments (peak II) were produced only during incubation with the *hpa* gene containing viruses. There was no degradation of the HSPG substrate by the culture medium of cells infected with control viruses.

FIG. 4 presents size fractionation of heparanase activity expressed by pF*hpa*2 infected cells. Culture medium of pF*hpa*2 infected High Five cells was applied onto a 50 kDa cut-off membrane. Heparanase activity (conversion of the peak I substrate, (◇) into peak II HS degradation fragments) was found in the high (> 50 kDa) (•), but not low (< 50 kDa) (○) molecular weight compartment.

FIGs. 5a-b demonstrate the effect of heparin on heparanase activity expressed by pF*hpa*2 and pF*hpa*4 infected High Five cells. Culture media of pF*hpa*2 (5a) and pF*hpa4* (5b) infected High Five cells were incubated (18 h, 37 °C) with sulfate labeled ECM-derived soluble HSPG (peak I, ◇) in the absence (•) or presence (△) of 10 μg/ml heparin. Production of low molecular weight HS degradation fragments was completely abolished in the presence of heparin, a potent inhibitor of heparanase activity (6, 7).

FIGs. 6a-b demonstrate degradation of sulfate labeled intact ECM by virus infected High Five and Sf21 cells. High Five (6a) and Sf21 (6b) cells were plated on sulfate labeled ECM and infected (48 h, 28 °C) with pF*hpa*4 (•) or control pF1 (□) viruses. Control non-infected Sf21 cells (R) were

plated on the labeled ECM as well. The pH of the cultured medium was adjusted to 6.0 - 6.2 followed by 24 h incubation at 37 °C. Sulfate labeled material released into the incubation medium was analyzed by gel filtration on Sepharose 6B. HS degradation fragments were produced only by cells infected with the *hpa* containing virus.

FIG. 7a-b demonstrate degradation of sulfate labeled intact ECM by virus infected cells. High Five (7a) and Sf21 (7b) cells were plated on sulfate labeled ECM and infected (48 h, 28 °C) with pF*hpa*4 (•) or control pF1 (□) viruses. Control non-infected Sf21 cells (R) were plate on labeled ECM as well. The pH of the cultured medium was adjusted to 6.0 - 6.2, followed by 48 h incubation at 28 °C. Sulfate labeled degradation fragments released into the incubation medium was analyzed by gel filtration on Sepharose 6B. HS degradation fragments were produced only by cells infected with the *hpa* containing virus.

FIGs. 8a-b demonstrate degradation of sulfate labeled intact ECM by the culture medium of pF*hpa4* infected cells. Culture media of High Five (8a) and Sf21 (8b) cells that were infected with pF*hpa*4 (•) or control pF1 (□) viruses were incubated (48 h, 37 °C, pH 6.0) with intact sulfate labeled ECM. The ECM was also incubated with the culture medium of control non-infected Sf21 cells (R). Sulfate labeled material released into the reaction mixture was subjected to gel filtration analysis. Heparanase activity was detected only in the culture medium of pF*hpa*4 infected cells.

FIGs. 9a-b demonstrate the effect of heparin on heparanase activity in the culture medium of pF*hpa*4 infected cells. Sulfate labeled ECM was incubated (24 h, 37 °C, pH 6.0) with culture medium of pF*hpa*4 infected High Five (9a) and Sf21 (9b) cells in the absence (•) or presence (V) of 10 μg/ml heparin. Sulfate labeled material released into the incubation medium was subjected to gel filtration on Sepharose 6B. Heparanase activity (production of peak II HS degradation fragments) was completely inhibited in the presence of heparin.

FIGs. 10a-b demonstrate purification of recombinant heparanase on heparin-Sepharose. Culture medium of Sf21 cells infected with pF*hpa*4 virus was subjected to heparin-Sepharose chromatography. Elution of fractions was performed with 0.35 - 2 M NaCl gradient (◇). Heparanase activity in the eluted fractions is demonstrated in Figure 10a (•). Fractions 15-28 were subjected to 15 % SDS-polyacrylamide gel electrophoresis followed by silver nitrate staining. A correlation is demonstrated between a

major protein band (MW ~ 63,000) in fractions 19 - 24 and heparanase activity.

FIGs. 11a-b demonstrate purification of recombinant heparanase on a Superdex 75 gel filtration column. Active fractions eluted from heparin-Sepharose (Figure 10a) were pooled, concentrated and applied onto Superdex 75 FPLC column. Fractions were collected and aliquots of each fraction were tested for heparanase activity (c, Figure 11a) and analyzed by SDS-polyacrylamide gel electrophoresis followed by silver nitrate staining (Figure 11b). A correlation is seen between the appearance of a major protein band (MW ~ 63,000) in fractions 4 - 7 and heparanase activity.

FIGs. 12a-e demonstrate expression of the *hpa* gene by RT-PCR with total RNA from human embryonal tissues (12a), human extra-embryonal tissues (12b) and cell lines from different origins (12c-e). RT-PCR products using *hpa* specific primers (I), primers for GAPDH housekeeping gene (II), and control reactions without reverse transcriptase demonstrating absence of genomic DNA or other contamination in RNA samples (III). M- DNA molecular weight marker VI (Boehringer Mannheim). For 12a: lane 1 - neutrophil cells (adult), lane 2 - muscle, lane 3 - thymus, lane 4 - heart, lane 5 - adrenal. For 12b: lane 1 - kidney, lane 2 - placenta (8 weeks), lane 3 - placenta (11 weeks), lanes 4-7 - mole (complete hydatidiform mole), lane 8 - cytotrophoblast cells (freshly isolated), lane 9 - cytotrophoblast cells (1.5 h *in vitro*), lane 10 - cytotrophoblast cells (6 h *in vitro*), lane 11 - cytotrophoblast cells (18 h *in vitro*), lane 12 - cytotrophoblast cells (48 h *in vitro*). For 12c: lane 1 - JAR bladder cell line, lane 2 - NCITT testicular tumor cell line, lane 3 - SW-480 human hepatoma cell line, lane 4 - HTR (cytotrophoblasts transformed by SV40), lane 5 - HPTLP-I hepatocellular carcinoma cell line, lane 6 - EJ-28 bladder carcinoma cell line. For 12d: lane 1 - SK-hep-1 human hepatoma cell line, lane 2 - DAMI human megakaryocytic cell line, lane 3 - DAMI cell line + PMA, lane 4 - CHRF cell line + PMA, lane 5 - CHRF cell line. For 12e: lane 1 - ABAE bovine aortic endothelial cells, lane 2 - 1063 human ovarian cell line, lane 3 - human breast carcinoma MDA435 cell line, lane 4 - human breast carcinoma MDA231 cell line.

FIG. 13 presents a comparison between nucleotide sequences of the human *hpa* and a mouse EST cDNA fragment (SEQ ID NO:12) which is 80 % homologous to the 3' end (starting at nucleotide 1066 of SEQ ID NO:9) of the human *hpa*. The aligned termination codons are underlined.

FIG. 14 demonstrates the chromosomal localization of the *hpa* gene. PCR products of DNA derived from somatic cell hybrids and of genomic DNA of hamster, mouse and human of were separated on 0.7 % agarose gel following amplification with *hpa* specific primers. Lane 1 – Lambda DNA digested with *Bst*EII, lane 2 – no DNA control, lanes 3 – 29, PCR amplification products. Lanes 3-5 – human, mouse and hamster genomic DNA, respectively. Lanes 6-29, human monochromosomal somatic cell hybrids representing chromosomes 1-22 and X and Y, respectively. Lane 30 – Lambda DNA digested with *Bst*EII. An amplification product of approximately 2.8 Kb is observed only in lanes 5 and 9, representing human genomic DNA and DNA derived from cell hybrid carrying human chromosome 4, respectively. These results demonstrate that the *hpa* gene is localized in human chromosome 4.

FIG. 15 demonstrates the genomic exon-intron structure of the human *hpa* locus (top) and the relative positions of the lambda clones used as sequencing templates to sequence the locus (below). The vertical rectangles represent exons (E) and the horizontal lines therebetween represent introns (I), upstream (U) and downstream (D) regions. Continuous lines represent DNA fragments, which were used for sequence analysis. The discontinuous line in lambda 6 represent a region, which overlaps with lambda 8 and hence was not analyzed. The plasmid contains a PCR product, which bridges the gap between L3 and L6.

FIG. 16 presents the nucleotide sequence of the genomic region of the *hpa* gene. Exon sequences appear in upper case and intron sequences in lower case. The deduced amino acid sequence of the exons is printed below the nucleotide sequence. Two predicted transcription start sites are shown in bold.

FIG. 17 presents an alignment of the amino acid sequences of human heparanase, mouse and partial sequences of rat homologues. The human and the mouse sequences were determined by sequence analysis of the isolated cDNAs. The rat sequence is derived from two different EST clones, which represent two different regions (5' and 3') of the rat *hpa* cDNA. The human sequence and the amino acids in the mouse and rat homologues, which are identical to the human sequence, appear in bold.

FIG. 18 presents a heparanase Zoo blot. Ten micrograms of genomic DNA from various sources were digested with *Eco*RI and separated on 0.7 % agarose – TBE gel. Following electrophoresis, the was gel treated with HCl and than with NaOH and the DNA fragments were downward

transferred to a nylon membrane (Hybond N+, Amersham) with 0.4 N NaOH. The membrane was hybridized with a 1.6 Kb DNA probe that contained the entire *hpa* cDNA. Lane order: H – Human; M – Mouse; Rt – Rat; P – Pig; Cw – Cow; Hr – Horse; S – Sheep; Rb – Rabbit; D – Dog; Ch – Chicken; F – Fish. Size markers (Lambda *Bst*eII) are shown on the left

FIG. 19 demonstrates the secondary structure prediction for heparanase performed using the PHD server – Profile network Prediction Heidelberg. H – helix, E – extended (beta strand), The glutamic acid predicted as the proton donor is marked by asterisk and the possible nucleophiles are underlined.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is of a polynucleotide or nucleic acid, referred to hereinbelow interchangeably as *hpa*, *hpa* cDNA or *hpa* gene or identified by its SEQ ID NOs, encoding a polypeptide having heparanase activity, vectors or nucleic acid constructs including same and which are used for over-expression or antisense inhibition of heparanase, genetically modified cells expressing same, recombinant protein having heparanase activity, antisense oligonucleotides and ribozymes for heparanase modulation, and heparanase promoter sequences which can be used to direct the expression of desired genes.

Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments or of being practiced or carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein is for the purpose of description and should not be regarded as limiting.

Cloning of the human and mouse *hpa* genes, cDNAs and genomic sequence (for human), encoding heparanase and expressing recombinant heparanase by transfected cells is reported herein. These are the first mammalian heparanase genes to be cloned.

A purified preparation of heparanase isolated from human hepatoma cells was subjected to tryptic digestion and microsequencing.

The YGPDVGQPR (SEQ ID NO:8) sequence revealed was used to screen EST databases for homology to the corresponding back translated

DNA sequences. Two closely related EST sequences were identified and were thereafter found to be identical.

Both clones contained an insert of 1020 bp which includes an open reading frame of 973 bp followed by a 3' untranslated region of 27 bp and a Poly A tail, whereas a translation start site was not identified.

Cloning of the missing 5' end was performed by PCR amplification of DNA from placenta Marathon RACE cDNA composite using primers selected according to the EST clones sequence and the linkers of the composite.

A 900 bp PCR fragment, partially overlapping with the identified 3' encoding EST clones was obtained. The joined cDNA fragment (*hpa*), 1721 bp long (SEQ ID NO:9), contained an open reading frame which encodes, as shown in Figure 1 and SEQ ID NO:11, a polypeptide of 543 amino acids (SEQ ID NO:10) with a calculated molecular weight of 61,192 daltons.

A single nucleotide difference at position 799 (A to T) between the EST clones and the PCR amplified cDNA was observed. This difference results in a single amino acid substitution (Tyr to Phe) (Figure 1). Furthermore, the published EST sequences contained an unidentified nucleotide, which following DNA sequencing of both the EST clones was resolved into two nucleotides (G and C at positions 1630 and 1631 in SEQ ID NO:9, respectively).

The ability of the *hpa* gene product to catalyze degradation of heparan sulfate in an *in vitro* assay was examined by expressing the entire open reading frame in insect cells, using the Baculovirus expression system.

Extracts and conditioned media of cells infected with virus containing the *hpa* gene, demonstrated a high level of heparan sulfate degradation activity both towards soluble ECM-derived HSPG and intact ECM, which was inhibited by heparin, while cells infected with a similar construct containing no *hpa* gene had no such activity, nor did non-infected cells.

The expression pattern of hpa RNA in various tissues and cell lines was investigated using RT-PCR. It was found to be expressed only in tissues and cells previously known to have heparanase activity.

Cloning an extended 5' sequence was enabled from the human SK-hep1 cell line by PCR amplification using the Marathon RACE. The 5' extended sequence of the SK-hep1 *hpa* cDNA was assembled with the sequence of the *hpa* cDNA isolated from human placenta (SEQ ID NO:9).

The assembled sequence contained an open reading frame, SEQ ID NOs: 13 and 15, which encodes, as shown in SEQ ID NOs:14 and 15, a polypeptide of 592 amino acids, with a calculated molecular weight of 66,407 daltons. This open reading frame was shown to direct the expression of catalytically active heparanase in a mammalian cell expression system. The expressed heparanase was detectable by anti heparanase antibodies in Western blot analysis.

A panel of monochromosomal human/CHO and human/mouse somatic cell hybrids was used to localize the human heparanase gene to human chromosome 4. The newly isolated heparanase sequence can therefore be used to identify a chromosome region harboring a human heparanase gene in a chromosome spread.

. The hpa cDNA was then used as a probe to screen a a human genomic library. Several phages were positive. These phages were analyzed and were found to cover most of the hpa locus, except for a small portion which was recovered by bridging PCR. The hpa locus covers about 50,000 bp. The hpa gene includes 12 exons separated by 11 introns.

RT-PCR performed on a variety of cells revealed alternatively spliced *hpa* transcripts.

The amino acid sequence of human heparanase was used to search for homologous sequences in the DNA and protein databases. Several human EST's were identified, as well as mouse sequences highly homologous to human heparanase. The following mouse EST's were identified AA177901, AA674378, AA67997, AA047943, AA690179, AI122034, all sharing an identical sequence and correspond to amino acids 336-543 of the human heparanase sequence. The entire mouse heparanase cDNA was cloned, based on the nucleotide sequence of the mouse EST's using Marathon cDNA libraries. The mouse and the human *hpa* genes share an average homology of 78 % between the nucleotide sequences and 81 % similarity between the deduced amino acid sequences. *hpa* homologous sequences from rat were also uncovered (EST's AI060284 and AI237828).

Homology search of heparanase amino acid sequence against the DNA and the protein databases and prediction of its protein secondary structure enabled to identify candidate amino acids that participate in the heparanase active site.

Expression of *hpa* antisense in mammalian cell lines resulted in about five fold decrease in the number of recoverable cells as compared to controls.

Human *Hpa* cDNA was shown to hybridize with genomic DNAs of a variety of mammalian species and with an avian.

The human and mouse *hpa* promoters were identified and the human promoter was tested positive in directing the expression of a reporter gene.

Thus, according to the present invention there is provided an isolated nucleic acid comprising a genomic, complementary or composite polynucleotide sequence encoding a polypeptide having heparanase catalytic activity.

The phrase "composite polynucleotide sequence" refers to a sequence which includes exonal sequences required to encode the polypeptide having heparanase activity, as well as any number of intronal sequences. The intronal sequences can be of any source and typically will include conserved splicing signal sequences. Such intronal sequences may further include cis acting expression regulatory elements.

The term "heparanase catalytic activity" or its equivalent term "heparanase activity" both refer to a mammalian endoglycosidase hydrolyzing activity which is specific for heparan or heparan sulfate proteoglycan substrates, as opposed to the activity of bacterial enzymes (heparinase I, II and III) which degrade heparin or heparan sulfate by means of β-elimination (37).

According to a preferred embodiment of the present invention the polynucleotide or a portion thereof is hybridizable with SEQ ID NOs: 9, 13, 42, 43 or a portion thereof at 68 °C in 6 x SSC, 1 % SDS, 5 x Denharts, 10 % dextran sulfate, 100 μg/ml salmon sperm DNA, and ^{32}p labeled probe and wash at 68 °C with 3, 2, 1, 0.5 or 0.1 x SSC and 0.1 % SDS.

According to another preferred embodiment of the present invention the polynucleotide or a portion thereof is at least 60 %, preferably at least 65 %, more preferably at least 70 %, more preferably at least 75 %, more preferably at least 80 %, more preferably at least 85 %, more preferably at least 90 %, most preferably, 95-100 % identical with SEQ ID NOs: 9, 13, 42, 43 or portions thereof as determined using the Bestfit procedure of the DNA sequence analysis software package developed by the Genetic Computer Group (GCG) at the university of Wisconsin (gap creation penalty - 12, gap extension penalty - 4 - which are the default parameters).

According to another preferred embodiment of the present invention the polypeptide encoded by the polynucleotide sequence is as set forth in SEQ ID NOs:10, 14, 44 or portions thereof having heparanase catalytic activity. Such portions are expected to include amino acids Asp-Glu 224-225 (SEQ ID NO:10), which can serve as proton donors and glutamic acid 343 or 396 which can serve as a nucleophile.

According to another preferred embodiment of the present invention the polypeptide encoded by the polynucleotide sequence is at least 60 %, preferably at least 65 %, more preferably at least 70 %, more preferably at least 75 %, more preferably at least 80 %, more preferably at least 85 %, more preferably at least 90 %, most preferably, 95-100 % homologous (both similar and identical acids) to SEQ ID NOs:10, 14, 44 or portions thereof as determined with the Smith-Waterman algorithm, using the Bioaccelerator platform developed by Compugene (gapop: 10.0, gapext: 0.5, matrix: blosum62, see also the description to Figure 17).

Further according to the present invention there is provided a nucleic acid construct comprising the isolated nucleic acid described herein. The construct may and preferably further include an origin of replication and

The construct or vector can be of any type. It may be a phage which infects bacteria or a virus which infects eukaryotic cells. It may also be a plasmid, phagemid, cosmid, bacmid or an artificial chromosome.

Further according to the present invention there is provided a host cell comprising the nucleic acid construct described herein. The host cell can be of any type. It may be a prokaryotic cell, an eukaryotic cell, a cell line, or a cell as a portion of an organism. The polynucleotide encoding heparanase can be permanently or transiently present in the cell. In other words, genetically modified cells obtained following stable or transient transfection, transformation or transduction are all within the scope of the present invention. The polynucleotide can be present in the cell in low copy (say 1-5 copies) or high copy number (say 5-50 copies or more). It may be integrated in one or more chromosomes at any location or be present as an extrachromosomal material.

The present invention is further directed at providing a heparanase over-expression system which includes a cell overexpressing heparanase catalytic activity. The cell may be a genetically modified host cell transiently or stably transfected or transformed with any suitable vector which includes a polynucleotide sequence encoding a polypeptide having

heparanase activity and a suitable promoter and enhancer sequences to direct over-expression of heparanase. However, the overexpressing cell may also be a product of an insertion (e.g., via homologous recombination) of a promoter and/or enhancer sequence downstream to the endogenous heparanase gene of the expressing cell, which will direct over-expression from the endogenous gene.

The term "over-expression" as used herein in the specification and claims below refers to a level of expression which is higher than a basal level of expression typically characterizing a given cell under otherwise identical conditions.

According to another aspect the present invention provides an antisense oligonucleotide comprising a polynucleotide or a polynucleotide analog of at least 10, preferably 11-15, more preferably 16-17, more preferably 18, more preferably 19-25, more preferably 26-35, most preferably 35-100 bases being hybridizable *in vivo*, under physiological conditions, with a portion of a polynucleotide strand encoding a polypeptide having heparanase catalytic activity. The antisense oligonucleotide can be used for downregulating heparanase activity by *in vivo* administration thereof to a patient. As such, the antisense oligonucleotide according to the present invention can be used to treat types of cancers which are characterized by impaired (over) expression of heparanase, and are dependent on the expression of heparanase for proliferating or forming metastases.

The antisense oligonucleotide can be DNA or RNA or even include nucleotide analogs, examples of which are provided in the Background section hereinabove. The antisense oligonucleotide according to the present invention can be synthetic and is preferably prepared by solid phase synthesis. In addition, it can be of any desired length which still provides specific base pairing (e.g., 8 or 10, preferably more, nucleotides long) and it can include mismatches that do not hamper base pairing under physiological conditions.

Further according to the present invention there is provided a pharmaceutical composition comprising the antisense oligonucleotide herein described and a pharmaceutically acceptable carrier. The carrier can be, for example, a liposome loadable with the antisense oligonucleotide.

According to a preferred embodiment of the present invention the antisense oligonucleotide further includes a ribozyme sequence. The ribozyme sequence serves to cleave a heparanase RNA molecule to which

the antisense oligonucleotide binds, to thereby downregulate heparanase expression.

Further according to the present invention there is provided an antisense nucleic acid construct comprising a promoter sequence and a polynucleotide sequence directing the synthesis of an antisense RNA sequence of at least 10 bases being hybridizable *in vivo*, under physiological conditions, with a portion of a polynucleotide strand encoding a polypeptide having heparanase catalytic activity. Like the antisense oligonucleotide, the antisense construct can be used for downregulating heparanase activity by *in vivo* administration thereof to a patient. As such, the antisense construct, like the antisense oligonucleotide, according to the present invention can be used to treat types of cancers which are characterized by impaired (over) expression of heparanase, and are dependent on the expression of heparanase for proliferating or forming metastases.

Thus, further according to the present invention there is provided a pharmaceutical composition comprising the antisense construct herein described and a pharmaceutically acceptable carrier. The carrier can be, for example, a liposome loadable with the antisense construct.

Formulations for topical administration may include, but are not limited to, lotions, ointments, gels, creams, suppositories, drops, liquids, sprays and powders. Conventional pharmaceutical carriers, aqueous, powder or oily bases, thickeners and the like may be necessary or desirable. Coated condoms, stents, active pads, and other medical devices may also be useful. Compositions for oral administration include powders or granules, suspensions or solutions in water or non-aqueous media, sachets, capsules or tablets. Thickeners, diluents, flavorings, dispersing aids, emulsifiers or binders may be desirable. Formulations for parenteral administration may include, but are not limited to, sterile aqueous solutions which may also contain buffers, diluents and other suitable additives.

Dosing is dependent on severity and responsiveness of the condition to be treated, but will normally be one or more doses per day, week or month with course of treatment lasting from several days to several months or until a cure is effected or a diminution of disease state is achieved. Persons ordinarily skilled in the art can easily determine optimum dosages, dosing methodologies and repetition rates.

Further according to the present invention there is provided a nucleic acid construct comprising a polynucleotide sequence functioning as a promoter, the polynucleotide sequence is derived from SEQ ID NO:42 and

includes at least nucleotides 2135-2635, preferably 2235-2635, more preferably 2335-2635, more preferably 2435-2635, most preferably 2535-2635 thereof, or SEQ ID NO:43 and includes at least nucleotides 1-420, preferably 120-420, more preferably 220-420, most preferably 320-420, thereof. These nucleotides are shown in the example section that follows to direct the synthesis of a reporter gene in transformed cells. Thus, further according to the present invention there is provided a method of expressing a polynucleotide sequence comprising the step of ligating the polynucleotide sequence downstream to either of the promoter sequences described herein. Heparanase promoters can be isolated from a variety of mammalian an other species by cloning genomic regions present 5' to the coding sequence thereof. This can be readily achievable by one ordinarily skilled in the art using the heparanase polynucleotides described herein, which are shown in the Examples section that follows to participate in efficient cross species hybridization.

Further according to the present invention there is provided a recombinant protein comprising a polypeptide having heparanase catalytic activity. The protein according to the present invention include modifications known as post translational modifications, including, but not limited to, proteolysis (e.g., removal of a signal peptide and of a pro- or preprotein sequence), methionine modification, glycosylation, alkylation (e.g., methylation), acetylation, etc. According to preferred embodiments the polypeptide includes at least a portion of SEQ ID NOs:10, 14 or 44, the portion has heparanase catalytic activity. According to preferred embodiments of the present invention the protein is encoded by any of the above described isolated nucleic acids. Further according to the present invention there is provided a pharmaceutical composition comprising, as an active ingredient, the recombinant protein described herein.

The recombinant protein may be purified by any conventional protein purification procedure close to homogeneity and/or be mixed with additives. The recombinant protein may be manufactured using any of the genetically modified cells described above, which include any of the expression nucleic acid constructs described herein. The recombinant protein may be in any form. It may be in a crystallized form, a dehydrated powder form or in solution. The recombinant protein may be useful in obtaining pure heparanase, which in turn may be useful in eliciting anti-heparanase antibodies, either poly or monoclonal antibodies, and as a

screening active ingredient in an anti-heparanase inhibitors or drugs screening assay or system.

Further according to the present invention there is provided a method of identifying a chromosome region harboring a human heparanase gene in a chromosome spread. the method is executed implementing the following method steps, in which in a first step the chromosome spread (either interphase or metaphase spread) is hybridized with a tagged polynucleotide probe encoding heparanase. The tag is preferably a fluorescent tag. In a second step according to the method the chromosome spread is washed, thereby excess of non-hybridized probe is removed. Finally, signals associated with the hybridized tagged polynucleotide probe are searched for, wherein detected signals being indicative of a chromosome region harboring the human heparanase gene. One ordinarily skilled in the art would know how to use the sequences disclosed herein in suitable labeling reactions and how to use the tagged probes to detect, using *in situ* hybridization, a chromosome region harboring a human heparanase gene.

Further according to the present invention there is provided a method of *in vivo* eliciting anti-heparanase antibodies comprising the steps of administering a nucleic acid construct including a polynucleotide segment corresponding to at least a portion of SEQ ID NOs:9, 13 or 43 and a promoter for directing the expression of said polynucleotide segment *in vivo*. Accordingly, there is provided also a DNA vaccine for *in vivo* eliciting anti-heparanase antibodies comprising a nucleic acid construct including a polynucleotide segment corresponding to at least a portion of SEQ ID NOs:9, 13 or 43 and a promoter for directing the expression of said polynucleotide segment *in vivo*. The vaccine optionally further includes a pharmaceutically acceptable carrier, such as a virus, liposome or an antigen presenting cell. Alternatively, the vaccine is employed as a naked DNA vaccine

The present invention can be used to develop treatments for various diseases, to develop diagnostic assays for these diseases and to provide new tools for basic research especially in the fields of medicine and biology.

Specifically, the present invention can be used to develop new drugs to inhibit tumor cell metastasis, inflammation and autoimmunity. The identification of the *hpa* gene encoding for the heparanase enzyme enables the production of a recombinant enzyme in heterologous expression systems.

Furthermore, the present invention can be used to modulate bioavailability of heparin-binding growth factors, cellular responses to heparin-binding growth factors (e.g., bFGF, VEGF) and cytokines (e.g., IL-8), cell interaction with plasma lipoproteins, cellular susceptibility to viral, protozoa and some bacterial infections, and disintegration of neurodegenerative plaques. Recombinant heparanase offers a potential treatment for wound healing, angiogenesis, restenosis, atherosclerosis, inflammation, neurodegenerative diseases (such as, for example, Genstmann-Straussler Syndrome, Creutzfeldt-Jakob disease, Scrape and Alzheimer's disease) and certain viral and some bacterial and protozoa infections. Recombinant heparanase can be used to neutralize plasma heparin, as a potential replacement of protamine.

As used herein, the term "modulate" includes substantially inhibiting, slowing or reversing the progression of a disease, substantially ameliorating clinical symptoms of a disease or condition, or substantially preventing the appearance of clinical symptoms of a disease or condition. A "modulator" therefore includes an agent which may modulate a disease or condition. Modulation of viral, protozoa and bacterial infections includes any effect which substantially interrupts, prevents or reduces any viral, bacterial or protozoa activity and/or stage of the virus, bacterium or protozoon life cycle, or which reduces or prevents infection by the virus, bacterium or protozoon in a subject, such as a human or lower animal.

As used herein, the term "wound" includes any injury to any portion of the body of a subject including, but not limited to, acute conditions such as thermal burns, chemical burns, radiation burns, burns caused by excess exposure to ultraviolet radiation such as sunburn, damage to bodily tissues such as the perineum as a result of labor and childbirth, including injuries sustained during medical procedures such as episiotomies, trauma-induced injuries including cuts, those injuries sustained in automobile and other mechanical accidents, and those caused by bullets, knives and other weapons, and post-surgical injuries, as well as chronic conditions such as pressure sores, bedsores, conditions related to diabetes and poor circulation, and all types of acne, etc.

Anti-heparanase antibodies, raised against the recombinant enzyme, would be useful for immunodetection and diagnosis of micrometastases, autoimmune lesions and renal failure in biopsy specimens, plasma samples, and body fluids. Such antibodies may also serve as neutralizing agents for heparanase activity.

The genomic heparanase sequences described herein can be used to construct knock-in and knock-out constructs. Such constructs include a fragment of 10-20 Kb of a heparanase locus and a negative and a positive selection markers and can be used to provide heparanase knock-in and knock-out animal models by methods known to the skilled artisan. Such animal models can be used for studying the function of heparanase in developmental processes, and in normal as well as pathological processes. They can also serve as an experimental model for testing drugs and gene therapy protocols. The complementary heparanase sequence (cDNA) can be used to derive transgenic animals, overexpressing heparanase for same. Alternatively , if cloned in the antisense orientation, the complementary heparanase sequence (cDNA) can be used to derive transgenic animals under-expressing heparanase for same.

The heparanase promoter sequences described herein and other cis regulatory elements linked to the heparanase locus can be used to regulated the expression of genes. For example, these promoters can be used to direct the expression of a cytotoxic protein, such as TNF, in tumor cells. It will be appreciated that heparanase itself is abnormally expressed under the control of its own promoter and other cis acting elements in a variety of tumors, and its expression is correlated with metastasis. It is also abnormally highly expressed in inflammatory cells. The introns of the heparanase gene can be used for the same purpose, as it is known that introns, especially upstream introns include cis acting element which affect expression. A heparanase promoter fused to a reporter protein can be used to study/monitor its activity.

The polynucleotide sequences described herein can also be used to provide DNA vaccines which will elicit in vivo anti heparanase antibodies. Such vaccines can therefore be used to combat inflammatory and cancer.

Antisense oligonucleotides derived according to the heparanase sequences described herein, especially such oligonucleotides supplemented with ribozyme activity, can be used to modulate heparanase expression. Such oligonucleotides can be from the coding region, from the introns or promoter specific. Antisense heparanase nucleic acid constructs can similarly function, as well known in the art.

The heparanase sequences described herein can be used to study the catalytic mechanism of heparanase. Carefully selected site directed mutagenesis can be employed to provide modified heparanase proteins

having modified characteristics in terms of, for example, substrate specificity, sensitivity to inhibitors, etc.

While studying heparanase expression in a variety of cell types alternatively spliced transcripts were identified. Such transcripts if found characteristic of certain pathological conditions can be used as markers for such conditions. Such transcripts are expected to direct the synthesis of heparanases with altered functions.

Additional objects, advantages, and novel features of the present invention will become apparent to one ordinarily skilled in the art upon examination of the following examples, which are not intended to be limiting. Additionally, each of the various embodiments and aspects of the present invention as delineated hereinabove and as claimed in the claims section below finds experimental support in the following examples.

EXAMPLES

Generally, the nomenclature used herein and the laboratory procedures in recombinant DNA technology described below are those well known and commonly employed in the art. Standard techniques are used for cloning, DNA and RNA isolation, amplification and purification. Generally enzymatic reactions involving DNA ligase, DNA polymerase, restriction endonucleases and the like are performed according to the manufacturers' specifications. These techniques and various other techniques are generally performed according to Sambrook et al., Molecular Cloning--A Laboratory Manual, Cold Spring Harbor Laboratory, Cold Spring Harbor, N.Y. (1989), which is incorporated herein by reference. Other general references are provided throughout this document. The procedures therein are believed to be well known in the art and are provided for the convenience of the reader. All the information contained therein is incorporated herein by reference.

The following protocols and experimental details are referenced in the Examples that follow:

Purification and characterization of heparanase from a human hepatoma cell line and human placenta: A human hepatoma cell line (Sk-hep-1) was chosen as a source for purification of a human tumor-derived heparanase. Purification was essentially as described in U.S. Pat. No. 5,362,641 to Fuks, which is incorporated by reference as if fully set forth

herein. Briefly, 500 liter, $5x10^{11}$ cells were grown in suspension and the heparanase enzyme was purified about 240,000 fold by applying the following steps: (i) cation exchange (CM-Sephadex) chromatography performed at pH 6.0, 0.3-1.4 M NaCl gradient; (ii) cation exchange (CM-Sephadex) chromatography performed at pH 7.4 in the presence of 0.1% CHAPS, 0.3-1.1 M NaCl gradient; (iii) heparin-Sepharose chromatography performed at pH 7.4 in the presence of 0.1% CHAPS, 0.35-1.1 M NaCl gradient; (iv) ConA-Sepharose chromatography performed at pH 6.0 in buffer containing 0.1 % CHAPS and 1 M NaCl, elution with 0.25 M α-methyl mannoside; and (v) HPLC cation exchange (Mono-S) chromatography performed at pH 7.4 in the presence of 0.1 % CHAPS, 0.25-1 M NaCl gradient.

Active fractions were pooled, precipitated with TCA and the precipitate subjected to SDS polyacrylamide gel electrophoresis and/or tryptic digestion and reverse phase HPLC. Tryptic peptides of the purified protein were separated by reverse phase HPLC (C8 column) and homogeneous peaks were subjected to amino acid sequence analysis.

The purified enzyme was applied to reverse phase HPLC and subjected to N-terminal amino acid sequencing using the amino acid sequencer (Applied Biosystems).

Cells: Cultures of bovine corneal endothelial cells (BCECs) were established from steer eyes as previously described (19, 38). Stock cultures were maintained in DMEM (1 g glucose/liter) supplemented with 10 % newborn calf serum and 5 % FCS. bFGF (1 ng/ml) was added every other day during the phase of active cell growth (13, 14).

Preparation of dishes coated with ECM: BCECs (second to fifth passage) were plated into 4-well plates at an initial density of 2 x 10^5 cells/ml, and cultured in sulfate-free Fisher medium plus 5 % dextran T-40 for 12 days. $Na_2{}^{35}SO_4$ (25 μCi/ml) was added on day 1 and 5 after seeding and the cultures were incubated with the label without medium change. The subendothelial ECM was exposed by dissolving (5 min., room temperature) the cell layer with PBS containing 0.5 % Triton X-100 and 20 mM NH_4OH, followed by four washes with PBS. The ECM remained intact, free of cellular debris and firmly attached to the entire area of the tissue culture dish (19, 22).

To prepare soluble sulfate labeled proteoglycans (peak I material), the ECM was digested with trypsin (25 μg/ml, 6 h, 37 °C), the digest was concentrated by reverse dialysis and the concentrated material was applied

onto a Sepharose 6B gel filtration column. The resulting high molecular weight material (Kav< 0.2, peak I) was collected. More than 80 % of the labeled material was shown to be composed of heparan sulfate proteoglycans (11, 39).

Heparanase activity: Cells (1 x 10^6/35-mm dish), cell lysates or conditioned media were incubated on top of ^{35}S-labeled ECM (18 h, 37 °C) in the presence of 20 mM phosphate buffer (pH 6.2). Cell lysates and conditioned media were also incubated with sulfate labeled peak I material (10-20 µl). The incubation medium was collected, centrifuged (18,000 x *g*, 4 °C, 3 min.), and sulfate labeled material analyzed by gel filtration on a Sepharose CL-6B column (0.9 x 30 cm). Fractions (0.2 ml) were eluted with PBS at a flow rate of 5 ml/h and counted for radioactivity using Bio-fluor scintillation fluid. The excluded volume (V_O) was marked by blue dextran and the total included volume (V_t) by phenol red. The latter was shown to comigrate with free sulfate (7, 11, 23). Degradation fragments of HS side chains were eluted from Sepharose 6B at 0.5 < Kav < 0.8 (peak II) (7, 11, 23). A nearly intact HSPG released from ECM by trypsin - and, to a lower extent, during incubation with PBS alone - was eluted next to V_O (Kav < 0.2, peak I). Recoveries of labeled material applied on the columns ranged from 85 to 95 % in different experiments (11). Each experiment was performed at least three times and the variation of elution positions (Kav values) did not exceed +/- 15 %.

Cloning of hpa cDNA: cDNA clones 257548 and 260138 were obtained from the I.M.A.G.E Consortium (2130 Memorial Parkway SW, Hunstville, AL 35801). The cDNAs were originally cloned in *Eco*RI and *Not*I cloning sites in the plasmid vector pT3T7D-Pac. Although these clones are reported to be somewhat different, DNA sequencing demonstrated that these clones are identical to one another. Marathon RACE (rapid amplification of cDNA ends) human placenta (poly-A) cDNA composite was a gift of Prof. Yossi Shiloh of Tel Aviv University. This composite is vector free, as it includes reverse transcribed cDNA fragments to which double, partially single stranded adapters are attached on both sides. The construction of the specific composite employed is described in reference 39a.

Amplification of hp3 PCR fragment was performed according to the protocol provided by Clontech laboratories. The template used for amplification was a sample taken from the above composite. The primers used for amplification were:

First step: 5'-primer: AP1: 5'-CCATCCTAATACGACTCACT ATAGGGC-3', SEQ ID NO:1; 3'-primer: HPL229: 5'-GTAGTGATGCCA TGTAACTGAATC-3', SEQ ID NO:2.

Second step: nested 5'-primer: AP2: 5'-ACTCACTATAGGGCTCG AGCGGC-3', SEQ ID NO:3; nested 3'- primer: HPL171: 5'-GCATCTTAGCCGTCTTTCTTCG-3', SEQ ID NO:4. The HPL229 and HPL171 were selected according to the sequence of the EST clones. They include nucleotides 933-956 and 876-897 of SEQ ID NO:9, respectively.

PCR program was 94 °C - 4 min., followed by 30 cycles of 94 °C - 40 sec., 62 °C - 1 min., 72 °C - 2.5 min. Amplification was performed with Expand High Fidelity (Boehringer Mannheim). The resulting ca. 900 bp hp3 PCR product was digested with *Bfr*I and *Pvu*II. Clone 257548 (p*hpa*1) was digested with *Eco*RI, followed by end filling and was then further digested with *Bfr*I. Thereafter the *Pvu*II - *Bfr*I fragment of the hp3 PCR product was cloned into the blunt end - *Bfr*I end of clone p*hpa*1 which resulted in having the entire cDNA cloned in pT3T7-pac vector, designated p*hpa*2.

RT-PCR: RNA was prepared using TRI-Reagent (Molecular research center Inc.) according to the manufacturer instructions. 1.25 μg were taken for reverse transcription reaction using MuMLV Reverse transcriptase (Gibco BRL) and Oligo $(dT)_{15}$ primer, SEQ ID NO:5, (Promega). Amplification of the resultant first strand cDNA was performed with *Taq* polymerase (Promega). The following primers were used:

HPU-355: 5'-TTCGATCCCAAGAAGGAATCAAC-3', SEQ ID NO:6, nucleotides 372-394 in SEQ ID NOs:9 or 11.

HPL-229: 5'-GTAGTGATGCCATGTAACTGAATC-3', SEQ ID NO:7, nucleotides 933-956 in SEQ ID NOs:9 or 11.

PCR program: 94 °C - 4 min., followed by 30 cycles of 94 °C - 40 sec., 62 °C - 1 min., 72 °C - 1 min.

Alternatively, total RNA was prepared from cell cultures using Tri-reagent (Molecular Research Center, Inc.) according to the manufacturer recommendation. Poly A+ RNA was isolated from total RNA using mRNA separator (Clontech). Reverse transcription was performed with total RNA using Superscript II (GibcoBRL). PCR was performed with Expand high fidelity (Boehringer Mannheim). Primers used for amplification were as follows:

Hpu-685, 5'-GAGCAGCCAGGTGAGCCCAAGAT-3', SEQ ID NO:24

Hpu-355, 5'-TTCGATCCCAAGAAGGAATCAAC-3', SEQ ID NO:25
Hpu 565, 5'-AGCTCTGTAGATGTGCTATACAC-3', SEQ ID NO:26
Hpl 967, 5'-TCAGATGCAAGCAGCAACTTTGGC-3', SEQ ID NO:27
Hpl 171, 5'-GCATCTTAGCCGTCTTTCTTCG-3', SEQ ID NO:28
Hpl 229, 5'-GTAGTGATGCCATGTAACTGAATC-3', SEQ ID NO:29

PCR reaction was performed as follows: 94 °C 3 minutes, followed by 32 cycles of 94 °C 40 seconds, 64 °C 1 minute, 72 °C 3 minutes, and one cycle 72 °C, 7 minutes.

Expression of recombinant heparanase in insect cells: Cells, High Five and Sf21 insect cell lines were maintained as monolayer cultures in SF900II-SFM medium (GibcoBRL).

Recombinant Baculovirus: Recombinant virus containing the *hpa* gene was constructed using the Bac to Bac system (GibcoBRL). The transfer vector pFastBac was digested with *Sal*I and *Not*I and ligated with a 1.7 kb fragment of p*hpa*2 digested with *Xho*I and *Not*I. The resulting plasmid was designated pFast*hpa*2. An identical plasmid designated pFast*hpa*4 was prepared as a duplicate and both independently served for further experimentations. Recombinant bacmid was generated according to the instructions of the manufacturer with pFast*hpa*2, pFast*hpa*4 and with pFastBac. The latter served as a negative control. Recombinant bacmid DNAs were transfected into Sf21 insect cells. Five days after transfection recombinant viruses were harvested and used to infect High Five insect cells, 3 x 10^6 cells in T-25 flasks. Cells were harvested 2 - 3 days after infection. 4 x 10^6 cells were centrifuged and resuspended in a reaction buffer containing 20 mM phosphate citrate buffer, 50 mM NaCl. Cells underwent three cycles of freeze and thaw and lysates were stored at -80 °C. Conditioned medium was stored at 4 °C.

Partial purification of recombinant heparanase: Partial purification of recombinant heparanase was performed by heparin-Sepharose column chromatography followed by Superdex 75 column gel filtration. Culture medium (150 ml) of Sf21 cells infected with pFhpa4 virus was subjected to heparin-Sepharose chromatography. Elution of 1 ml fractions was performed with 0.35 - 2 M NaCl gradient in presence of 0.1 % CHAPS and 1 mM DTT in 10 mM sodium acetate buffer, pH 5.0. A 25 µl sample of each fraction was tested for heparanase activity. Heparanase activity was eluted at the range of 0.65 - 1.1 M NaCl (fractions 18-26, Figure 10a). 5 µl of each fraction was subjected to 15 % SDS-polyacrylamide gel electrophoresis followed by silver nitrate staining.

Active fractions eluted from heparin-Sepharose (Figure 10a) were pooled and concentrated (x 6) on YM3 cut-off membrane. 0.5 ml of the concentrated material was applied onto 30 ml Superdex 75 FPLC column equilibrated with 10 mM sodium acetate buffer, pH 5.0, containing 0.8 M NaCl, 1 mM DTT and 0.1 % CHAPS. Fractions (0.56 ml) were collected at a flow rate of 0.75 ml/min. Aliquots of each fraction were tested for heparanase activity and were subjected to SDS-polyacrylamide gel electrophoresis followed by silver nitrate staining (Figure 11b).

PCR amplification of genomic DNA: 94 °C 3 minutes, followed by 32 cycles of 94 °C 45 seconds, 64 °C 1 minute, 68 °C 5 minutes, and one cycle at 72 °C, 7 minutes. Primers used for amplification of genomic DNA included:

GHpu-L3 5'-AGGCACCCTAGAGATGTTCCAG-3', SEQ ID NO:30
GHpl-L6 5'-GAAGATTTCTGTTTCCATGACGTG-3', SEQ ID NO:31.

Screening of genomic libraries: A human genomic library in Lambda phage EMBLE3 SP6/T7 (Clontech, Paulo Alto, CA) was screened. 5 x 10^5 plaques were plated at 5 x 10^4 pfu/plate on NZCYM agar/top agarose plates. Phages were absorbed on nylon membranes in duplicates (Qiagen). Hybridization was performed at 65 °C in 5 x SSC, 5 x Denhart's, 10 % dextran sulfate, 100 μg/ml Salmon sperm, ^{32}p labeled probe (10^6 cpm/ml). A 1.6 kb fragment, containing the entire *hpa* cDNA was labeled by random priming (Boehringer Mannheim). Following hybridization membranes were washed once with 2 x SSC, 0.1 % SDS at 65 °C for 20 minutes, and twice with 0.2 x SSC, 0.1 % SDS at 65 °C for 15 minutes. Hybridizing plaques were picked, and plated at 100 pfu/plate. Hybridization was performed as above and single isolated positive plaques were picked.

Phage DNA was extracted using a Lambda DNA extraction kit (Qiagen). DNA was digested with *Xho*I and *Eco*RI, separated on 0.7 % agarose gel and transferred to nylon membrane Hybond N+ (Amersham). Hybridization and washes were performed as above.

cDNA Sequence analysis: Sequence determinations were performed with vector specific and gene specific primers, using an automated DNA sequencer (Applied Biosystems, model 373A). Each nucleotide was read from at least two independent primers.

Genomic sequence analysis: Large-scale sequencing was performed by Commonwealth Biotechnology Incorporation.

Isolation of mouse hpa: Mouse *hpa* cDNA was amplified from either Marathon ready cDNA library of mouse embryo or from mRNA isolated from mouse melanoma cell line BL6, using the Marathon RACE kit from Clontech. Both procedures were performed according to the manufacturer's recommendation.

Primers used for PCR amplification of mouse hpa:

Mhpl773 5'-CCACACTGAATGTAATACTGAAGTG-3', SEQ ID NO:32
MHpl736 5'-CGAAGCTCTGGAACTCGGCAAG-3', SEQ ID NO:33
MHpl83 5'-GCCAGCTGCAAAGGTGTTGGAC-3', SEQ ID NO:34
Mhpl152 5'-AACACCTGCCTCATCACGACTTC-3', SEQ ID NO:35
Mhpl114 5'-GCCAGGCTGGCGTCGATGGTGA-3', SEQ ID NO:36
MHpl103 5'-GTCGATGGTGATGGACAGGAAC-3', SEQ ID NO:37
Ap1 5'-GTAATACGACTCACTATAGGGC-3', SEQ ID NO:38 - (Genome walker)
Ap2 5'-ACTATAGGGCACGCGTGGT-3', SEQ ID NO:39 - (Genome walker)
Ap1 5'-CCATCCTAATACGACTCACTATAGGGC-3', SEQ ID NO:40 - (Marathon RACE)
Ap2 5'-ACTCACTATAGGGCTCGAGCGGC-3', SEQ ID NO:41 - (Marathon RACE)

Southern analysis of genomic DNA: Genomic DNA was extracted from animal or from human blood using Blood and cell culture DNA maxi kit (Qiagene). DNA was digested with *Eco*RI, separated by gel electrophoresis and transferred to a nylon membrane Hybond N+ (Amersham). Hybridization was performed at 68 °C in 6 x SSC, 1 % SDS, 5 x Denharts, 10 % dextran sulfate, 100 μg/ml salmon sperm DNA, and ^{32}p labeled probe. A 1.6 kb fragment, containing the entire *hpa* cDNA was used as a probe. Following hybridization, the membrane was washed with 3 x SSC, 0.1 % SDS, at 68 °C and exposed to X-ray film for 3 days. Membranes were then washed with 1 x SSC, 0.1 % SDS, at 68 °C and were reexposed for 5 days.

Construction of hpa promoter-GFP expression vector: Lambda DNA of phage L3, was digested with *Sac*I and *Bgl*II, resulting in a 1712 bp fragment which contained the *hpa* promoter (877-2688 of SEQ ID NO:42). The pEGFP-1 plasmid (Clontech) was digested with *Bgl*II and *Sac*I and ligated with the 1712 bp fragment of the *hpa* promoter sequence. The resulting plasmid was designated phpEGL. A second *hpa* promoter-GFP plasmid was constructed containing a shorter fragment of the *hpa* promoter

region: phpEGL was digested with *Hind*III, and the resulting 1095 bp fragment (nucleotides 1593-2688 of SEQ ID NO:42) was ligated with *Hind*III digested pEGFP-1. The resulting plasmid was designated phpEGS.

Computer analysis of sequences: Homology searches were performed using several computer servers, and various databases. Blast 2.0 service, at the NCBI server was used to screen the protein database swplus and DNA databases such as GenBank, EMBL, and the EST databases. Blast 2.0 search was performed using the basic search option of the NCBI server. Sequence analysis and alignments were done using the DNA sequence analysis software package developed by the Genetic Computer Group (GCG) at the university of Wisconsin. Alignments of two sequences were performed using Bestfit (gap creation penalty - 12, gap extension penalty - 4). Protein homology search was performed with the Smith-Waterman algorithm, using the Bioaccelerator platform developed by Compugene. The protein database swplus was searched using the following parameters: gapop: 10.0, gapext: 0.5, matrix: blosum62. Blocks homology was performed using the Blocks WWW server developed at Fred Hutchinson Cancer Research Center in Seattle, Washington, USA. Secondary structure prediction was performed using the PHD server – Profile network Prediction Heidelberg. Fold recognition (threading) was performed using the UCLA-DOE structure prediction server. The method used for prediction was gonnet+predss. Alignment of three sequences was performed using the pileup application (gap creation penalty - 5, gap extension penalty - 1). Promoter analysis was performed using TSSW and TSSG programs (BCM Search Launcher Human Genome Center, Baylor College of Medicine, Houston TX).

EXAMPLE 1

Cloning of human hpa cDNA

Purified fraction of heparanase isolated from human hepatoma cells (SK-hep-1) was subjected to tryptic digestion and microsequencing. EST (Expressed Sequence Tag) databases were screened for homology to the back translated DNA sequences corresponding to the obtained peptides. Two EST sequences (accession Nos. N41349 and N45367) contained a DNA sequence encoding the peptide YGPDVGQPR (SEQ ID NO:8). These two sequences were derived from clones 257548 and 260138 (I.M.A.G.E Consortium) prepared from 8 to 9 weeks placenta cDNA library (Soares). Both clones which were found to be identical contained an insert

of 1020 bp which included an open reading frame (ORF) of 973 bp followed by a 3' untranslated region of 27 bp and a Poly A tail. No translation start site (AUG) was identified at the 5' end of these clones.

Cloning of the missing 5' end was performed by PCR amplification of DNA from a placenta Marathon RACE cDNA composite. A 900 bp fragment (designated hp3), partially overlapping with the identified 3' encoding EST clones was obtained.

The joined cDNA fragment, 1721 bp long (SEQ ID NO:9), contained an open reading frame which encodes, as shown in Figure 1 and SEQ ID NO:11, a polypeptide of 543 amino acids (SEQ ID NO:10) with a calculated molecular weight of 61,192 daltons. The 3' end of the partial cDNA inserts contained in clones 257548 and 260138 started at nucleotide G^{721} of SEQ ID NO:9 and Figure 1.

As further shown in Figure 1, there was a single sequence discrepancy between the EST clones and the PCR amplified sequence, which led to an amino acid substitution from Tyr^{246} in the EST to Phe^{246} in the amplified cDNA. The nucleotide sequence of the PCR amplified cDNA fragment was verified from two independent amplification products. The new gene was designated *hpa*.

As stated above, the 3' end of the partial cDNA inserts contained in EST clones 257548 and 260138 started at nucleotide 721 of *hpa* (SEQ ID NO:9). The ability of the *hpa* cDNA to form stable secondary structures, such as stem and loop structures involving nucleotide stretches in the vicinity of position 721 was investigated using computer modeling. It was found that stable stem and loop structures are likely to be formed involving nucleotides 698-724 (SEQ ID NO:9). In addition, a high GC content, up to 70 %, characterizes the 5' end region of the *hpa* gene, as compared to about only 40 % in the 3' region. These findings may explain the immature termination and therefore lack of 5' ends in the EST clones.

To examine the ability of the *hpa* gene product to catalyze degradation of heparan sulfate in an *in vitro* assay the entire open reading frame was expressed in insect cells, using the Baculovirus expression system. Extracts of cells, infected with virus containing the *hpa* gene, demonstrated a high level of heparan sulfate degradation activity, while cells infected with a similar construct containing no *hpa* gene had no such activity, nor did non-infected cells. These results are further demonstrated in the following Examples.

EXAMPLE 2

Degradation of soluble ECM-derived HSPG

Monolayer cultures of High Five cells were infected (72 h, 28 °C) with recombinant Bacoluvirus containing the pFast*hpa* plasmid or with control virus containing an insert free plasmid. The cells were harvested and lysed in heparanase reaction buffer by three cycles of freezing and thawing. The cell lysates were then incubated (18 h, 37 °C) with sulfate labeled, ECM-derived HSPG (peak I), followed by gel filtration analysis (Sepharose 6B) of the reaction mixture.

As shown in Figure 2, the substrate alone included almost entirely high molecular weight (Mr) material eluted next to V_O (peak I, fractions 5-20, Kav < 0.35). A similar elution pattern was obtained when the HSPG substrate was incubated with lysates of cells that were infected with control virus. In contrast, incubation of the HSPG substrate with lysates of cells infected with the *hpa* containing virus resulted in a complete conversion of the high Mr substrate into low Mr labeled degradation fragments (peak II, fractions 22-35, 0.5 < Kav < 0.75).

Fragments eluted in peak II were shown to be degradation products of heparan sulfate, as they were (i) 5- to 6-fold smaller than intact heparan sulfate side chains (Kav approx. 0.33) released from ECM by treatment with either alkaline borohydride or papain; and (ii) resistant to further digestion with papain or chondroitinase ABC, and susceptible to deamination by nitrous acid (6, 11). Similar results (not shown) were obtained with Sf21 cells. Again, heparanase activity was detected in cells infected with the *hpa* containing virus (pF*hpa*), but not with control virus (pF). This result was obtained with two independently generated recombinant viruses. Lysates of control not infected High Five cells failed to degrade the HSPG substrate.

In subsequent experiments, the labeled HSPG substrate was incubated with medium conditioned by infected High Five or Sf21 cells.

As shown in Figures 3a-b, heparanase activity, reflected by the conversion of the high Mr peak I substrate into the low Mr peak II which represents HS degradation fragments, was found in the culture medium of cells infected with the pF*hpa*2 or pF*hpa*4 viruses, but not with the control pF1 or pF2 viruses. No heparanase activity was detected in the culture medium of control non-infected High Five or Sf21 cells.

The medium of cells infected with the pF*hpa*4 virus was passed through a 50 kDa cut off membrane to obtain a crude estimation of the

molecular weight of the recombinant heparanase enzyme. As demonstrated in Figure 4, all the enzymatic activity was retained in the upper compartment and there was no activity in the flow through (<50 kDa) material. This result is consistent with the expected molecular weight of the *hpa* gene product.

In order to further characterize the *hpa* product the inhibitory effect of heparin, a potent inhibitor of heparanase mediated HS degradation (40) was examined.

As demonstrated in Figures 5a-b, conversion of the peak I substrate into peak II HS degradation fragments was completely abolished in the presence of heparin.

Altogether, these results indicate that the heparanase enzyme is expressed in an active form by insect cells infected with Baculovirus containing the newly identified human *hpa* gene.

EXAMPLE 3

Degradation of HSPG in intact ECM

Next, the ability of intact infected insect cells to degrade HS in intact, naturally produced ECM was investigated. For this purpose, High Five or Sf21 cells were seeded on metabolically sulfate labeled ECM followed by infection (48 h, 28 °C) with either the pF*hpa*4 or control pF2 viruses. The pH of the medium was then adjusted to pH 6.2-6.4 and the cells further incubated with the labeled ECM for another 48 h at 28 °C or 24 h at 37 °C. Sulfate labeled material released into the incubation medium was analyzed by gel filtration on Sepharose 6B.

As shown in Figures 6a-b and 7a-b, incubation of the ECM with cells infected with the control pF2 virus resulted in a constant release of labeled material that consisted almost entirely (>90%) of high Mr fragments (peak I) eluted with or next to V_o. It was previously shown that a proteolytic activity residing in the ECM itself and/or expressed by cells is responsible for release of the high Mr material (6). This nearly intact HSPG provides a soluble substrate for subsequent degradation by heparanase, as also indicated by the relatively large amount of peak I material accumulating when the heparanase enzyme is inhibited by heparin (6, 7, 12, Figure 9). On the other hand, incubation of the labeled ECM with cells infected with the pF*hpa*4 virus resulted in release of 60-70% of the ECM-associated radioactivity in the form of low Mr sulfate-labeled fragments (peak II, 0.5 <Kav< 0.75), regardless of whether the infected cells were incubated with

the ECM at 28 °C or 37 °C. Control intact non-infected Sf21 or High Five cells failed to degrade the ECM HS side chains.

In subsequent experiments, as demonstrated in Figures 8a-b, High Five and Sf21 cells were infected (96 h, 28 °C) with pF*hpa*4 or control pF1 viruses and the culture medium incubated with sulfate-labeled ECM. Low Mr HS degradation fragments were released from the ECM only upon incubation with medium conditioned by pF*hpa*4 infected cells. As shown in Figure 9, production of these fragments was abolished in the presence of heparin. No heparanase activity was detected in the culture medium of control, non-infected cells. These results indicate that the heparanase enzyme expressed by cells infected with the pF*hpa*4 virus is capable of degrading HS when complexed to other macromolecular constituents (i.e. fibronectin, laminin, collagen) of a naturally produced intact ECM, in a manner similar to that reported for highly metastatic tumor cells or activated cells of the immune system (6, 7).

EXAMPLE 4

Purification of recombinant human heparanase

The recombinant heparanase was partially purified from medium of pF*hpa*4 infected Sf21 cells by Heparin-Sepharose chromatography (Figure 10a) followed by gel filtration of the pooled active fractions over an FPLC Superdex 75 column (Figure 11a). A ~ 63 kDa protein was observed, whose quantity, as was detected by silver stained SDS-polyacrylamide gel electrophoresis, correlated with heparanase activity in the relevant column fractions (Figures 10b and 11b, respectively). This protein was not detected in the culture medium of cells infected with the control pF1 virus and was subjected to a similar fractionation on heparin-Sepharose (not shown).

EXAMPLE 5

Expression of the human hpa cDNA in various cell types, organs and tissues

Referring now to Figures 12a-e, RT-PCR was applied to evaluate the expression of the *hpa* gene by various cell types and tissues. For this purpose, total RNA was reverse transcribed and amplified. The expected 585 bp long cDNA was clearly demonstrated in human kidney, placenta (8 and 11 weeks) and mole tissues, as well as in freshly isolated and short termed (1.5-48 h) cultured human placental cytotrophoblastic cells (Figure 12a), all known to express a high heparanase activity (41). The *hpa*

transcript was also expressed by normal human neutrophils (Figure 12b). In contrast, there was no detectable expression of the *hpa* mRNA in embryonic human muscle tissue, thymus, heart and adrenal (Figure 12b). The *hpa* gene was expressed by several, but not all, human bladder carcinoma cell lines (Figure 12c), SK hepatoma (SK-hep-1), ovarian carcinoma (OV 1063), breast carcinoma (435, 231), melanoma and megakaryocytic (DAMI, CHRF) human cell lines (Figures 12d-e).

The above described expression pattern of the *hpa* transcript was determined to be in a very good correlation with heparanase activity levels determined in various tissues and cell types (not shown).

EXAMPLE 6

Isolation of an extended 5' end of hpa cDNA from human SK-hep1 cell line

The 5' end of *hpa* cDNA was isolated from human SK-hep1 cell line by PCR amplification using the Marathon RACE (rapid amplification of cDNA ends) kit (Clontech). Total RNA was prepared from SK-hep1 cells using the TRI-Reagent (Molecular research center Inc.) according to the manufacturer instructions. Poly A+ RNA was isolated using the mRNA separator kit (Clonetech).

The Marahton RACE SK-hep1 cDNA composite was constructed according to the manufacturer recommendations. First round of amplification was performed using an adaptor specific primer AP1: 5'-CCATCCTAATACG ACTCACTATAGGGC-3', SEQ ID NO:1, and a *hpa* specific antisense primer hpl-629: 5'-CCCCAGGAGCAGCAGCATCAG-3', SEQ ID NO:17, corresponding to nucleotides 119-99 of SEQ ID NO:9. The resulting PCR product was subjected to a second round of amplification using an adaptor specific nested primer AP2: 5'-ACTCACTATAGGGCTCGAGCGGC-3', SEQ ID NO:3, and a *hpa* specific antisense nested primer hpl-666 5'-AGGCTTCGAGCGCAGCAGCAT-3', SEQ ID NO:18, corresponding to nucleotides 83-63 of SEQ ID NO:9. The PCR program was as follows: a hot start of 94 °C for 1 minute, followed by 30 cycles of 90 °C - 30 seconds, 68 °C - 4 minutes. The resulting 300 bp DNA fragment was extracted from an agarose gel and cloned into the vector pGEM-T Easy (Promega). The resulting recombinant plasmid was designated pHPSK1.

The nucleotide sequence of the pHPSK1 insert was determined and it was found to contain 62 nucleotides of the 5' end of the placenta *hpa* cDNA

(SEQ ID NO:9) and additional 178 nucleotides upstream, the first 178 nucleotides of SEQ ID NOs:13 and 15.

A single nucleotide discrepancy was identified between the SK-hep1 cDNA and the placenta cDNA. The "T" derivative at position 9 of the placenta cDNA (SEQ ID NO:9), is replaced by a "C" derivative at the corresponding position 187 of the SK-hep1 cDNA (SEQ ID NO:13).

The discrepancy is likely to be due to a mutation at the 5' end of the placenta cDNA clone as confirmed by sequence analysis of sevsral additional cDNA clones isolated from placenta, which like the SK-hep1 cDNA contained C at position 9 of SEQ ID NO:9.

The 5' extended sequence of the SK-hep1 *hpa* cDNA was assembled with the sequence of the *hpa* cDNA isolated from human placenta (SEQ ID NO:9). The assembled sequence contained an open reading frame which encodes, as shown in SEQ ID NOs:14 and 15, a polypeptide of 592 amino acids with a calculated molecular weight of 66,407 daltons. The open reading frame is flanked by 93 bp 5' untranslated region (UTR).

EXAMPLE 7

Isolation of the upstream genomic region of the hpa gene

The upstream region of the *hpa* gene was isolated using the Genome Walker kit (Clontech) according to the manufacturer recommendations. The kit includes five human genomic DNA samples each digested with a different restriction endonuclease creating blunt ends: *Eco*RV, *Sca*I, *Dra*I, *Pvu*II and *Ssp*I.

The blunt ended DNA fragments are ligated to partially single stranded adaptors. The Genomic DNA samples were subjected to PCR amplification using the adaptor specific primer and a gene specific primer. Amplification was performed with Expand High Fidelity (Boehringer Mannheim).

A first round of amplification was performed using the ap1 primer: 5'-G TAATACGACTCACTATAGGGC-3', SEQ ID NO:19, and the *hpa* specific antisense primer hpl-666: 5'-AGGCTTCGAGCGCAGCAGCAT-3', SEQ ID NO:18, corresponding to nucleotides 83 – 63 of SEQ ID NO:9. The PCR program was as follows: a hot start of 94 °C - 3 minutes, followed by 36 cycles of 94 °C - 40 seconds, 67 °C - 4 minutes.

The PCR products of the first amplification were diluted 1:50. One µl of the diluted sample was used as a template for a second amplification using a nested adaptor specific primer ap2: 5'-

ACTATAGGGCACGCGTGGT-3', SEQ ID NO:20, and a *hpa* specific antisense primer hpl-690, 5'-CTTGGGCTCACC TGGCTGCTC-3', SEQ ID NO:21, corresponding to nucleotides 62-42 of SEQ ID NO:9. The resulting amplification products were analyzed using agarose gel electrophoresis. Five different PCR products were obtained from the five amplification reactions. A DNA fragment of approximately 750 bp which was obtained from the *Ssp*I digested DNA sample was gel extracted. The purified fragment was ligated into the plasmid vector pGEM-T Easy (Promega). The resulting recombinant plasmid was designated pGHP6905 and the nucleotide sequence of the *hpa* insert was determined.

A partial sequence of 594 nucleotides is shown in SEQ ID NO:16. The last nucleotide in SEQ ID NO:13 corresponds to nucleotide 93 in SEQ ID:13. The DNA sequence in SEQ ID NO:16 contains the 5' region of the *hpa* cDNA and 501 nucleotides of the genomic upstream region which are predicted to contain the promoter region of the *hpa* gene.

EXAMPLE 8

Expression of the 592 amino acids HPA polypeptide in a human 293 cell line

The 592 amino acids open reading frame (SEQ ID NOs:13 and 15) was constructed by ligation of the 110 bp corresponding to the 5' end of the SK-hep1 *hpa* cDNA with the placenta cDNA. More specifically the Marathon RACE - PCR amplification product of the placenta *hpa* DNA was digested with *Sac*I and an approximately 1 kb fragment was ligated into a *Sac*I-digested pGHP6905 plasmid. The resulting plasmid was digested with *Ear*I and *Aat*II. The *Ear*I sticky ends were blunted and an approximately 280 bp *Ear*I/blunt-*Aat*II fragment was isolated. This fragment was ligated with pFast*hpa* digested with *Eco*RI which was blunt ended using Klenow fragment and further digested with *Aat*II. The resulting plasmid contained a 1827 bp insert which includes an open reading frame of 1776 bp, 31 bp of 3' UTR and 21 bp of 5' UTR. This plasmid was designated pFastL*hpa*.

A mammalian expression vector was constructed to drive the expression of the 592 amino acids heparanase polypeptide in human cells. The *hpa* cDNA was excised prom pFastL*hpa* with *Bss*HII and *Not*I. The resulting 1850 bp *Bss*HII-*Not*I fragment was ligated to a mammalian expression vector pSI (Promega) digested with *Mlu*I and *Not*I. The resulting recombinant plasmid, pSI*hpa*Met2 was transfected into a human 293 embryonic kidney cell line.

Transient expression of the 592 amino-acids heparanase was examined by western blot analysis and the enzymatic activity was tested using the gel shift assay. Both these procedures are described in length in U.S. Pat. application No. 09/071,739, filed May 1, 1998, which is incorporated by reference as if fully set forth herein. Cells were harvested 3 days following transfection. Harvested cells were re-suspended in lysis buffer containing 150 mM NaCl, 50 mM Tris pH 7.5, 1% Triton X-100, 1 mM PMSF and protease inhibitor cocktail (Boehringer Mannheim). 40 μg protein extract samples were used for separation on a SDS-PAGE. Proteins were transferred onto a PVDF Hybond-P membrane (Amersham). The membrane was incubated with an affinity purified polyclonal anti heparanase antibody, as described in U.S. Pat. application No. 09/071,739. A major band of approximately 50 kDa was observed in the transfected cells as well as a minor band of approximately 65 kDa. A similar pattern was observed in extracts of cells transfected with the pS*hpa* as demonstrated in U.S. Pat. application No. 09/071,739. These two bands probably represent two forms of the recombinant heparanase protein produced by the transfected cells. The 65 kDa protein probably represents a heparanase precursor, while the 50 kDa protein is suggested herein to be the processed or mature form.

The catalytic activity of the recombinant protein expressed in the pS*hpa*Met2 transfected cells was tested by gel shift assay. Cell extracts of transfected and of mock transfected cells were incubated overnight with heparin (6 μg in each reaction) at 37 °C, in the presence of 20 mM phosphate citrate buffer pH 5.4, 1 mM $CaCl_2$, 1 mM DTT and 50 mM NaCl. Reaction mixtures were then separated on a 10 % polyacrylamide gel. The catalytic activity of the recombinant heparanase was clearly demonstrated by a faster migration of the heparin molecules incubated with the transfected cell extract as compared to the control. Faster migration indicates the disappearance of high molecular weight heparin molecules and the generation of low molecular weight degradation products.

EXAMPLE 9

Chromosomal localization of the hpa gene

Chromosomal mapping of the *hpa* gene was performed utilizing a panel of monochromosomal human/CHO and human/mouse somatic cell hybrids, obtained from the UK HGMP Resource Center (Cambridge, England).

40 ng of each of the somatic cell hybrid DNA samples were subjected to PCR amplification using the *hpa* primers: hpu565 5'-AGCTCTGTAGATGTGC TATACAC-3', SEQ ID NO:22, corresponding to nucleotides 564-586 of SEQ ID NO:9 and an antisense primer hpl171 5'-GCATCTTAGCCGTCTTTCTTCG-3', SEQ ID NO:23, corresponding to nucleotides 897-876 of SEQ ID NO:9.

The PCR program was as follows: a hot start of 94 °C – 3 minutes, followed by 7 cycles of 94 °C – 45 seconds, 66 °C – 1 minute, 68 °C – 5 minutes, followed by 30 cycles of 94 °C – 45 seconds, 62 °C – 1 minute, 68 °C – 5 minutes, and a 10 minutes final extension at 72 °C.

The reactions were performed with Expand long PCR (Boehringer Mannheim). The resulting amplification products were analyzed using agarose gel electrophoresis. As demonstrated in Figure 14, a single band of approximately 2.8 Kb was obtained from chromosome 4, as well as from the control human genomic DNA. A 2.8 kb amplification product is expected based on amplification of the genomic *hpa* clone (data not shown). No amplification products were obtained neither in the control DNA samples of hamster and mouse nor in somatic hybrids of other human chromosome.

EXAMPLE 10

Human genomic clone encoding heparanase

Five plaques were isolated following screening of a human genomic library and were designated L3-1, L5-1, L8-1, L10-1 and L6-1. The phage DNAs were analyzed by Southern hybridization and by PCR with *hpa* specific and vector specific primers. Southern analysis was performed with three fragments of *hpa* cDNA: a *Pvu*II-*Bam*HI fragment (nucleotides 32-450, SEQ ID NO:9), a *Bam*HI-*Nde*I fragment (nucleotides 451-1102, SEQ ID NO:9) and an *Nde*I-*Xho*I fragment (nucleotides 1103-1721, SEQ ID NO:9).

Following Southern analysis, phages L3, L6, L8 were selected for further analysis. A scheme of the genomic region and the relative position of the three phage clones is depicted in Figure 15. A 2 kb DNA fragment containing the gap between phages L6 and L3 was PCR amplified from human genomic DNA with two gene specific primers GHpuL3 and GHplL6. The PCR product was cloned into the plasmid vector pGEM-T-easy (Promega).

Large scale DNA sequencing of the three Lambda clones and the amplified fragment was performed with Lambda purified DNA by primer walking. A nucleotide sequence of 44,898 bp was analyzed (Figure 16, SEQ ID NO:42). Comparison of the genomic sequence with that of *hpa* cDNA revealed 12 exons separated by 11 introns (Figures 15 an 16). The genomic organization of the *hpa* gene is depicted in Figure 15 (top). The sequence include the coding region from the first ATG to the stop codon which spans 39,113 nucleotides, 2742 nucleotides upstream of the first ATG and 3043 nucleotides downstream of the stop codon. Splice site consensus sequences were identified at exon/intron junctions.

EXAMPLE 11

Alternative splicing

Several minor RT-PCR products were obtained from various cell types, following amplification with *hpa* specific primers. Each one found to contain a deletion of one or two exons. Some of these PCR products contain ORFs, which encode potential shorter proteins.

Table 1 below summarizes the alternative spliced products isolated from various cell lines.

Fragments of similar sizes were obtained following amplification with two cell lines, placenta and platelets.

Cell type	Nucleotides deleted	Exons deleted	ORF
Platelets	1047-1267	8, 9	+
Platelets	1154-1267	9	-
Platelets	289-435, 562-735	2, 4	-
Sk-hep1, platelets, Zr75	562-735	4	+
Sk-hep1 (hepatoma)	561-904	4, 5	-
Zr75 (breast carcinoma)	96-203	1 (partial)	+

EXAMPLE 12

Mouse and rat hpa

EST databases were screened for sequences homologous to the *hpa* gene. Three mouse EST's were identified (accession No. Aa177901, from mouse spleen, Aa067997 from mouse skin, Aa47943 from mouse embryo), assembled into a 824 bp cDNA fragment which contains a partial open reading frame (lacking a 5' end) of 629 bp and a 3' untranslated region of

195 bp (SEQ ID NO:12). As shown in Figure 13, the coding region is 80 % similar to the 3' end of the *hpa* cDNA sequence. These EST's are probably cDNA fragments of the mouse *hpa* homolog that encodes for the mouse heparanase.

Searching for consensus protein domains revealed an amino terminal homology between the heparanase and several precursor proteins such as Procollagen Alpha 1 precursor, Tyrosine-protein kinase-RYK, Fibulin-1, Insulin-like growth factor binding protein and several others. The amino terminus is highly hydrophobic and contains a potential trans-membrane domain. The homology to known signal peptide sequences suggests that it could function as a signal peptide for protein localization.

The amino acid sequence of human heparanase was used to search for homologous sequences in the DNA and protein databases. Several human EST's were identified, as well as mouse sequences highly homologous to human heparanase. The following mouse EST's were identified AA177901, AA674378, AA67997, AA047943, AA690179, AI122034, all sharing an identical sequence and correspond to amino acids 336-543 of the human heparanase sequence. The entire mouse heparanase cDNA was cloned, based on the nucleotide sequence of the mouse EST's. PCR primers were designed and a Marathon RACE was performed using a Marathon cDNA library from 15 days mouse embryo (Clontech) and from BL6 mouse melanoma cell line. The mouse *hpa* homologous cDNA was isolated following several amplification steps. A 1.1 kb fragment was amplified from mouse embryo Marathon cDNA library. The first cycle of amplification was performed with primers mhpl773 and Ap1 and the second cycle with primers mhpl736 and AP2. A 1.1 kb fragment was then amplified from BL6 Marathon cDNA library. The first cycle of amplification was performed with the primers mhpl152 and Ap1, and the second with mhpl83 and AP2. The combined sequence was homologous to nucleotides 157 - 1702 of the human *hpa* cDNA, which encode amino acids 33-543. The 5' end of the mouse *hpa* gene was isolated from a mouse genomic DNA library using the Genome Walker kit (Clontech). An 0.9 kb fragment was amplified from a *Dra*I digested Genome walker DNA library. The first cycle of amplification was performed with primers mhpl114 and Ap1 and the second with primers mhpl103 and AP2. The assembled sequence (SEQ ID NOs:43, 45) is 2396 nucleotides long. It contains an open reading frame of 1605 nucleotides, which encode a polypeptide of 535 amino acids (SEQ ID NOs:44, 45), 196 nucleotides of 3' untranslated

region (UTR), and anupstream sequence which includes the promoter region and the 5'-UTR of the mouse *hpa* cDNA.. According to two promoter predicting programs TSSW and TSSG, the transcription start site is localized to nucleotide 431 of SEQ ID NOs:43, 45, 163 nucleotides upstream of the first ATG codon. The 431 upstream genomic sequence contains the promoter region. A TATA box is predicted at position 394 of SEQ ID NOs:43, 45. The mouse and the human *hpa* genes share an average homology of 78 % between the nucleotide sequences and 81 % similarity between the deduced amino acid sequences.

Search for *hpa* homologous sequences, using the Blast 2.0 server revealed two EST's from rat: AI060284 (385 nucleotides, SEQ ID NO:46) which is homologous to the amino terminus (68 % similarity to amino acids 12-136) of human heparanase and AI237828 (541 nucleotides, SEQ ID NO:47) which is homologous to the carboxyl terminus (81 % similarity to amino acids 500-543) of human heparanase, and contains a 3'-UTR. A comparison between the human heparanase and the mouse and rat homologous sequences is demonstrated in Figure 17.

EXAMPLE 13

Prediction of heparanase active site

Homology search of heparanase amino acid sequence against the DNA and the protein databases revealed no significant homologies. The protein secondary structure as predicted by the PHD program consists of alternating alpha helices and beta sheets. The fold recognition server of UCLA predicted alpha/beta barrel structure, with under-threshold confidence.

Five of 15 proteins, which were predicted to have most similar folds, were glycosyl hydrolases from various organisms: 1xyza – xylanase from Clostridium Thermocellum, 1pbga – 6-phospho-beta-δ-galactosidase from Lactococcus Lactis, 1amy – alpha-amylase from Barley, 1ecea – endocellulase from Acidothermus Cellulolyticus and 1qbc – hexosaminidase alpha chain, glycosyl hydrolase.

Protein homology search using the bioaccelerator pulled out several proteins, including glycosyl hydrolyses such as beta-fructofuranosidase from *Vicia faba* (broad bean) and from potato, lactase phlorizin hydrolase from human, xylanases from *Clostridium thermocellum* and from *Streptomyces halstedii* and cellulase from *Clostridium thermocellum*. Blocks 9.3 database pulled out the active site of glycosyl hydrolases family

five, which includes cellulases from various bacteria and fungi. Similar active site motif is shared by several lysosomal acid hydrolases (63) and other glycosyl hydrolases. The common mechanism shared by these enzymes involves two glutamic acid residues, a proton donor and a nucleophile.

Despite the lack of an overall homology between the heparanase and other glycosyl hydolases, the amino acid couple Asp-Glu (NE), which is characteristic of the proton donor of glycosyl hydrolyses of the GH-A clan, was found at positions 224-225 of the human heparanase protein sequence. As in other clan members, this NE couple is located at the end of a β sheet.

Considering the relative location of the proton donor and the predicted secondary structure, the glutamic acid that functions as nucleophile is most likely located at position 343, or at positon 396. Identification of the active site and the amino acids directly involved in hydrolysis opens the way for expression of the defined catalytic domain. In addition, it will provide the tools for rational design of enzyme activity either by modification of the microenviroment or catalytic site itself.

EXAMPLE 14

Expression of hpa antisense in mammalian cell lines

A mammalian expression vector Hpa2Kepcdna3 was constructed in order to express *hpa* antisense in mammalian cells. *hpa* cDNA (1.7 kb *Eco*RI fragment) was cloned into the plasmid pCDNA3 in 3'>5' (antisense) orientation. The construct was used to transfect MBT2-T50 and T24P cell lines. 2 x 10^5 cells in 35 mm plates were transfected using the Fugene protocol (Boehringer Mannheim). 48 hours after transfection cells were trypsinized and seeded in six well plates. 24 hours later G418 was added to initiate selection. The number of colonies per 35 mm plate following 3 weeks:

	Antisense	No insert
T24P	15	60
MBT-T50	1	6

The lower number of colonies obtained after transfection with *hpa* antisense, as compared with the control plasmid suggests that the introduction of *hpa* antisense interfere with cell growth. This experiment demonstrates the use of complementary antisense *hpa* DNA sequence to

control heparanase expression in cells. This approach may be used to inhibit expression of heparanase *in vivo*, in, for example, cancer cells and in other pathological processes in which heparanase is involved.

EXAMPLE 15

Zoo blot

Hpa cDNA was used as a probe to detect homologous sequences in human DNA and in DNA of various animals. The autoradiogram of the Southern analysis is presented in Figure 18. Several bands were detected in human DNA, which correlated with the accepted pattern according to the genomic *hpa* sequence. Several intense bands were detected in all mammals, while faint bands were detected in chicken. This correlates with the phylogenetic relation between human and the tested animals. The intense bands indicate that *hpa* is conserved among mammals as well as in more genetically distant organisms. The multiple bands patterns suggest that in all animals, like in human, the *hpa* locus occupy large genomic region. Alternatively, the various bands could represent homologous sequences and suggest the existence of a gene family, which can be isolated based on their homology to the human *hpa* reported herein. This conservation was actually found, between the isolated human *hpa* cDNA and the mouse homologue.

EXAMPLE 16

Characterization of the hpa promoter

The DNA sequence upstream of the *hpa* first ATG was subjected to computational analysis in order to localize the predicted transcription start site and to identify potential transcription factors binding sites. Recognition of human PolII promoter region and start of transcription were predicted using the TSSW and TSSG programs. Both programs identified a promoter region upstream of the coding region. TSSW pointed at nucleotide 2644 and TSSG at 2635 of SEQ ID NO:42. These two predicted transcription start sites are located 4 and 13 nucleotides upstream of the longest *hpa* cDNA isolated by RACE.

A *hpa* promoter-GFP reporter vector was constructed in order to investigate the regulation of *hpa* transcription. Two constructs were made, containing 1.8 kb and 1.1 kb of the *hpa* promoter region. The reporter vector was transfected into T50-mouse bladder carcinoma cells. Cells transfected with both constructs exhibited green fluorescence, which

indicated the promoter activity of the genomic sequence upstream of the *hpa*-coding region. This reporter vector, enables the monitoring of hpa promoter activity, at various conditions and in different cell types and to characterize the factors involved regulation of *hpa* expression.

Although the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims.

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74. Agrawal (1992) Antisense oligonucleotides as antiviral agents. TIBTECH 10:152.

75. Uhlmann et al. (1990) Chem. Rev. 90:544.

76. Cook (1991) Medicinal chemistry of antisense oligonucleotides - future opportunities. Anti-Cancer Drug Design 6:585.

77. Biotechnology research news (1993) Can DNA mimics improve on the real thing? Science 262:1647.

WHAT IS CLAIMED IS:

1. An isolated nucleic acid comprising a genomic, complementary or composite polynucleotide sequence encoding a polypeptide having heparanase catalytic activity.

2. The isolated nucleic acid of claim 1, wherein said polynucleotide or a portion thereof is hybridizable with SEQ ID NOs: 9, 13, 42, 43 or a portion thereof at 68 °C in 6 x SSC, 1 % SDS, 5 x Denharts, 10 % dextran sulfate, 100 μg/ml salmon sperm DNA, and ^{32}p labeled probe and wash at 68 °C with 3 x SSC and 0.1 % SDS.

3. The isolated nucleic acid of claim 1, wherein said polynucleotide or a portion thereof is at least 60 % identical with SEQ ID NOs: 9, 13, 42, 43 or portions thereof as determined using the Bestfit procedure of the DNA sequence analysis software package developed by the Genetic Computer Group (GCG) at the university of Wisconsin (gap creation penalty - 12, gap extension penalty - 4).

4. The isolated nucleic acid of claim 1, wherein said polypeptide is as set forth in SEQ ID NOs:10, 14, 44 or portions thereof.

5. The isolated nucleic acid of claim 1, wherein said polypeptide is at least 60 % homologous to SEQ ID NOs:10, 14, 44 or portions thereof as determined with the Smith-Waterman algorithm, using the Bioaccelerator platform developed by Compugene (gapop: 10.0, gapext: 0.5, matrix: blosum62).

6. A nucleic acid construct comprising the isolated nucleic acid of claim 1.

7. A host cell comprising the nucleic acid construct of claim 6.

8. An antisense oligonucleotide comprising a polynucleotide or a polynucleotide analog of at least 10 bases being hybridizable *in vivo*, under physiological conditions, with a portion of a polynucleotide strand encoding a polypeptide having heparanase catalytic activity.

9. The antisense oligonucleotide of claim 8, wherein said polynucleotide strand encoding said polypeptide having heparanase catalytic activity is as set forth in SEQ ID NOs: 9, 13, 42, or 43.

10. The antisense oligonucleotide of claim 8, wherein said polypeptide having heparanase catalytic activity is as set forth in SEQ ID NOs: 10, 14 and 44.

11. A method of *in vivo* downregulating heparanase activity comprising the step of *in vivo* administering the antisense oligonucleotide of claim 8.

12. A pharmaceutical composition comprising the antisense oligonucleotide of claim 8 and a pharmaceutically acceptable carrier.

13. A ribozyme comprising the antisense oligonucleotide of claim 8 and a ribozyme sequence.

14. An antisense nucleic acid construct comprising a promoter sequence and a polynucleotide sequence directing the synthesis of an antisense RNA sequence of at least 10 bases being hybridizable *in vivo*, under physiological conditions, with a portion of a polynucleotide strand encoding a polypeptide having heparanase catalytic activity.

15. The antisense nucleic acid construct of claim 14, wherein said polynucleotide strand encoding said polypeptide having heparanase catalytic activity is as set forth in SEQ ID NOs: 9, 13, 42 or 43.

16. The antisense nucleic acid construct of claim 14, wherein said polypeptide having heparanase catalytic activity is as set forth in SEQ ID NOs: 10, 14 or 44.

17. A method of *in vivo* downregulating heparanase activity comprising the step of *in vivo* administering the antisense nucleic acid construct of claim 14.

18. A pharmaceutical composition comprising the antisense nucleic acid construct of claim 14 and a pharmaceutically acceptable carrier.

19. A nucleic acid construct comprising a polynucleotide sequence functioning as a promoter, said polynucleotide sequence is derived from SEQ ID NO:42 and includes at least nucleotides 2535-2635 thereof or from SEQ ID NO:43 and includes at least nucleotides 320-420.

20. A method of expressing a polynucleotide sequence comprising the step of ligating the polynucleotide sequence into the nucleic acid construct of claim 19, downstream of said polynucleotide sequence derived from SEQ ID NOs:42 or 43.

21. A recombinant protein comprising a polypeptide having heparanase catalytic activity.

22. The recombinant protein of claim 21, wherein said polypeptide includes at least a portion of SEQ ID NOs:10, 14 or 44.

23. The recombinant protein of claim 21, wherein the protein is encoded by a polynucleotide hybridizable with SEQ ID NOs: 9, 13, 42, 43 or a portion thereof at 68 °C in 6 x SSC, 1 % SDS, 5 x Denharts, 10 % dextran sulfate, 100 μg/ml salmon sperm DNA, and ^{32}p labeled probe and wash at 68 °C with 3 x SSC and 0.1 % SDS.

24. The recombinant protein of claim 21, wherein the protein is encoded by a polynucleotide at least 60 % identical with SEQ ID NOs: 9, 13, 42, 43 or portions thereof as determined using the Bestfit procedure of the DNA sequence analysis software package developed by the Genetic Computer Group (GCG) at the university of Wisconsin (gap creation penalty - 12, gap extension penalty - 4).

25. A pharmaceutical composition comprising, as an active ingredient, the recombinant protein of claim 21.

26. A method of identifying a chromosome region harboring a heparanase gene in a chromosome spread comprising the steps of:

(a) hybridizing the chromosome spread with a tagged polynucleotide probe encoding heparanase;

(b) washing the chromosome spread, thereby removing excess of non-hybridized probe; and

(c) searching for signals associated with said hybridized tagged polynucleotide probe, wherein detected signals being indicative of a chromosome region harboring a heparanase gene.

27. A method of *in vivo* eliciting anti-heparanase antibodies comprising the steps of administering a nucleic acid construct including a polynucleotide segment corresponding to at least a portion of SEQ ID NOs:9, 13 or 43 and a promoter for directing the expression of said polynucleotide segment *in vivo*.

28. A DNA vaccine for *in vivo* eliciting anti-heparanase antibodies comprising a nucleic acid construct including a polynucleotide segment corresponding to at least a portion of SEQ ID NOs:9, 13 or 43 and a promoter for directing the expression of said polynucleotide segment *in vivo*.

Fig 1

1 CTAGAGCTTTCGACTCTCCGCTGCGCGGCAGCTGGCGGGGGGAGCAGCCAGGTGAGCCCA

61 AGATGCTGCTGCGCTCGAAGCCTGCGCTGCCGCCGCCGCTGATGCTGCTGCTCCTGGGGC

M L L R S K P A L P P P L M L L L L G P

121 CGCTGGGTCCCCTCTCCCCTGGCGCCCTGCCCCGACCTGCGCAAGCACAGGACGTCGTGG

L G P L S P G A L P R P A Q A Q D V V D

181 ACCTGGACTTCTTCACCCAGGAGCCGCTGCACCTGGTGAGCCCCTCGTTCCTGTCCGTCA

L D F F T Q E P L H L V S P S F L S V T

241 CCATTGACGCCAACCTGGCCACGGACCCGCGGTTCCTCATCCTCCTGGGTTCTCCAAAGC

I D A N L A T D P R F L I L L G S P K L

301 TTCGTACCTTGGCCAGAGGCTTGTCTCCTGCGTACCTGAGGTTTGGTGGCACCAAGACAG

R T L A R G L S P A Y L R F G G T K T D

361 ACTTCCTAATTTTCGATCCCAAGAAGGAATCAACCTTTGAAGAGAGAAGTTACTGGCAAT

F L I F D P K K E S T F E E R S Y W Q S

421 CTCAAGTCAACCAGGATATTTGCAAATATGGATCCATCCCTCCTGATGTGGAGGAGAAGT

Q V N Q D I C K Y G S I P P D V E E K L

481 TACGGTTGGAATGGCCCTACCAGGAGCAATTGCTACTCCGAGAACACTACCAGAAAAAGT

R L E W P Y Q E Q L L L R E H Y Q K K F

541 TCAAGAACAGCACCTACTCAAGAAGCTCTGTAGATGTGCTATACACTTTTGCAAACTGCT

K N S T Y S R S S V D V L Y T F A N C S

601 CAGGACTGGACTTGATCTTTGGCCTAAATGCGTTATTAAGAACAGCAGATTTGCAGTGGA

G L D L I F G L N A L L R T A D L Q W N

661 ACAGTTCTAATGCTCAGTTGCTCCTGGACTACTGCTCTTCCAAGGGGTATAACATTTCTT

S S N A Q L L L D Y C S S K G Y N I S W

721 GGGAACTAGGCAATGAACCTAACAGTTTCCTTAAGAAGGCTGATATTTTCATCAATGGGT

E L G N E P N S F L K K A D I F I N G S

(T)

781 CGCAGTTAGGAGAAGATTATATTCAATTGCATAAACTTCTAAGAAAGTCCACCTTCAAAA

Q L G E D Y I Q L H K L L R K S T F K N

(F)

841 ATGCAAAACTCTATGGTCCTGATGTTGGTCAGCCTCGAAGAAAGACGGCTAAGATGCTGA

A K L Y G P D V G Q P R R K T A K M L K

901 AGAGCTTCCTGAAGGCTGGTGGAGAAGTGATTGATTCAGTTACATGGCATCACTACTATT

S F L K A G G E V I D S V T W H H Y Y L

961 TGAATGGACGGACTGCTACCAGGGAAGATTTTCTAAACCCTGATGTATTGGACATTTTTA

N G R T A T R E D F L N P D V L D I F I

1021 TTTCATCTGTGCAAAAAGTTTTCCAGGTGGTTGAGAGCACCAGGCCTGGCAAGAAGGTCT

S S V Q K V F Q V V E S T R P G K K V W

1081 GGTTAGGAGAAACAAGCTCTGCATATGGAGGCGGAGCGCCCTTGCTATCCGACACCTTTG

L G E T S S A Y G G G A P L L S D T F A

1141 CAGCTGGCTTTATGTGGCTGGATAAATTGGGCCTGTCAGCCCGAATGGGAATAGAAGTGG

A G F M W L D K L G L S A R M G I E V V

1201 TGATGAGGCAAGTATTCTTTGGAGCAGGAAACTACCATTTAGTGGATGAAAACTTCGATC

M R Q V F F G A G N Y H L V D E N F D P

1261 CTTTACCTGATTATTGGCTATCTCTTCTGTTCAAGAAATTGGTGGGCACCAAGGTGTTAA

L P D Y W L S L L F K K L V G T K V L M

1321 TGGCAAGCGTGCAAGGTTCAAAGAGAAGGAAGCTTCGAGTATACCTTCATTGCACAAACA

A S V Q G S K R R K L R V Y L H C T N T

1381 CTGACAATCCAAGGTATAAAGAAGGAGATTTAACTCTGTATGCCATAAACCTCCATAACG

D N P R Y K E G D L T L Y A I N L H N V

1441 TCACCAAGTACTTGCGGTTACCCTATCCTTTTTCTAACAAGCAAGTGGATAAATACCTTC

T K Y L R L P Y P F S N K Q V D K Y L L

1501 TAAGACCTTTGGGACCTCATGGATTACTTTCCAAATCTGTCCAACTCAATGGTCTAACTC

R P L G P H G L L S K S V Q L N G L T L

1561 TAAAGATGGTGGATGATCAAACCTTGCCACCTTTAATGGAAAAACCTCTCCGGCCAGGAA

K M V D D Q T L P P L M E K P L R P G S

1621 GTTCACTGGGCTTGCCAGCTTTCTCATATAGTTTTTTTGTGATAAGAAATGCCAAAGTTG

S L G L P A F S Y S F F V I R N A K V A

1681 CTGCTTGCATCTGAAAATAAAATATACTAGTCCTGACACTG

A C I

FIG. 2

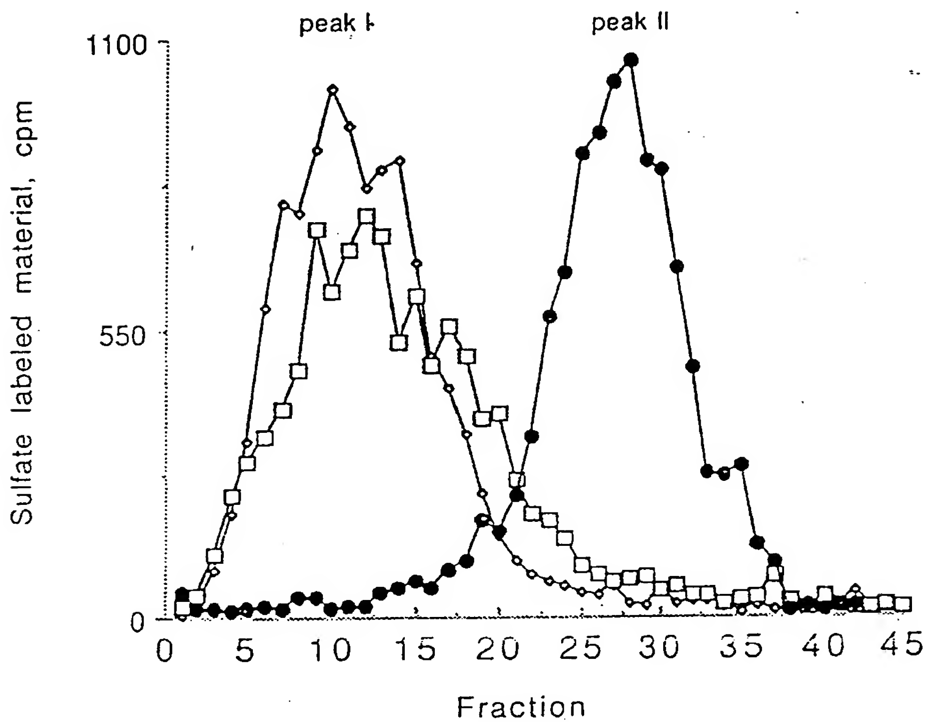
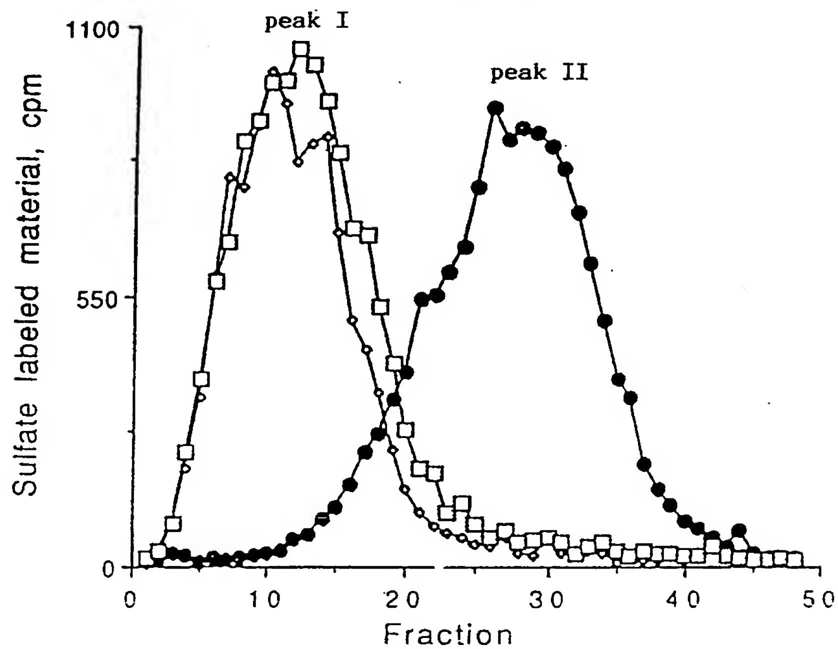

peak I
peak II
1100
550
0
Sulfate labeled material, cpm
0
5
10
15
20
25
30
35
40
45
Fraction

FIG. 3A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peak II
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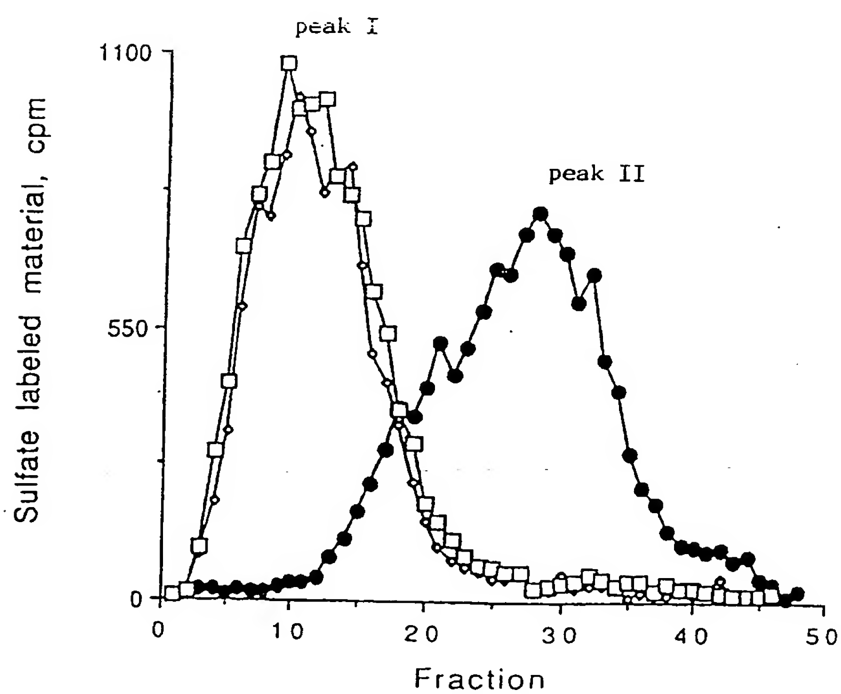
550
0
Sulfate labeled material, cpm
0
10
20
30
40
50
Fraction

FIG. 3B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peak II
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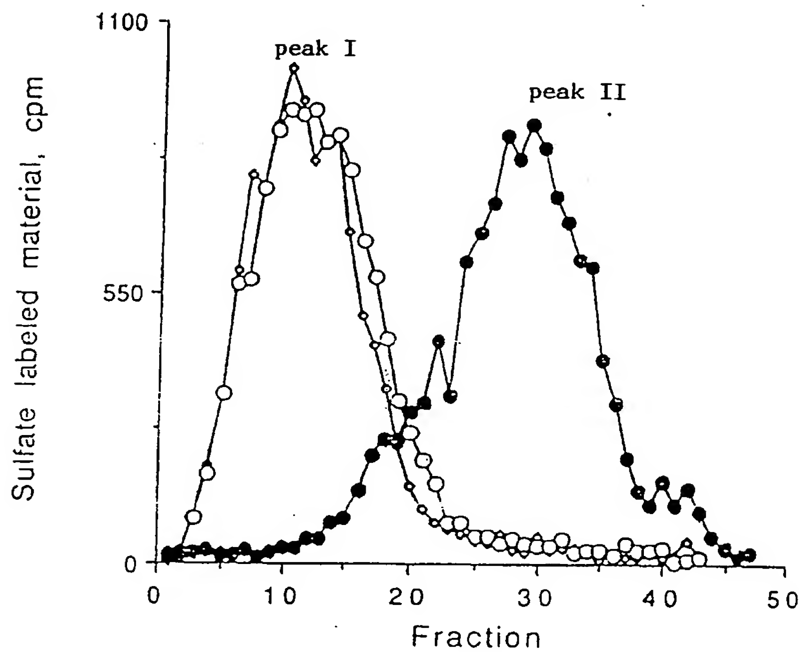
550
0
Sulfate labeled material, cpm
0
10
20
30
40
50
Fraction

FIG. 4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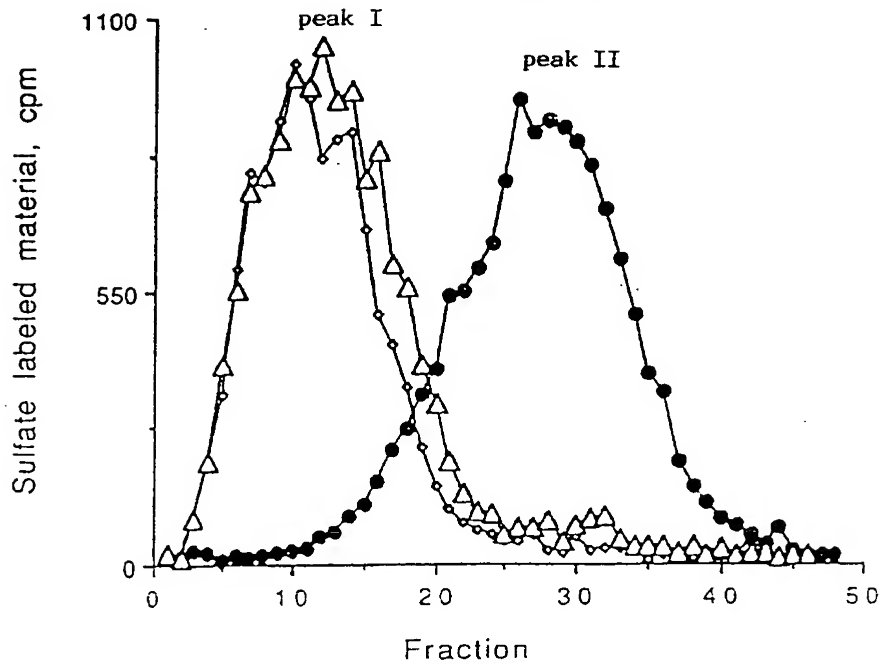
550
0
peak I
peak II
Sulfate labeled material, cpm
0
10
20
30
40
50
Fraction

FIG. 5A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peak II
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550
0
0
10
20
30
40
50
Sulfate labeled material, cpm
Fraction

FIG. 5B

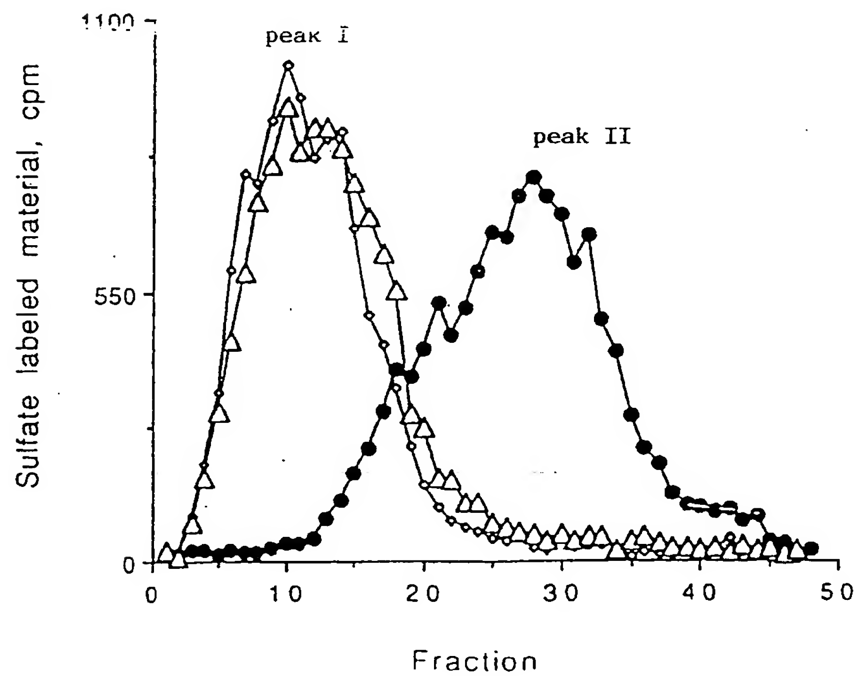

peak I
peak II
550
0
0
10
20
30
40
50
Sulfate labeled material, cpm
Fraction

FIG. 6A

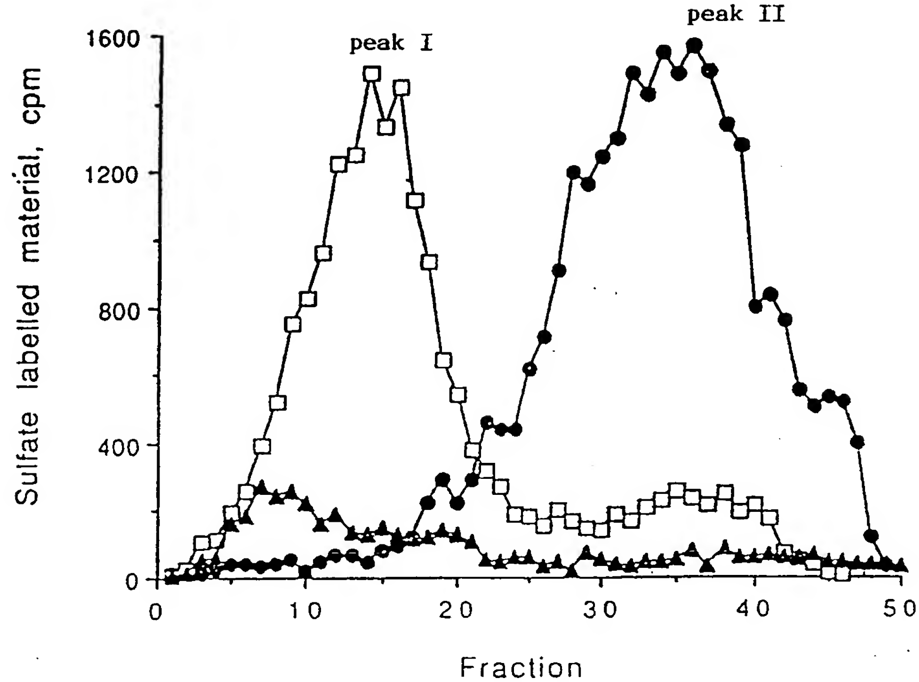
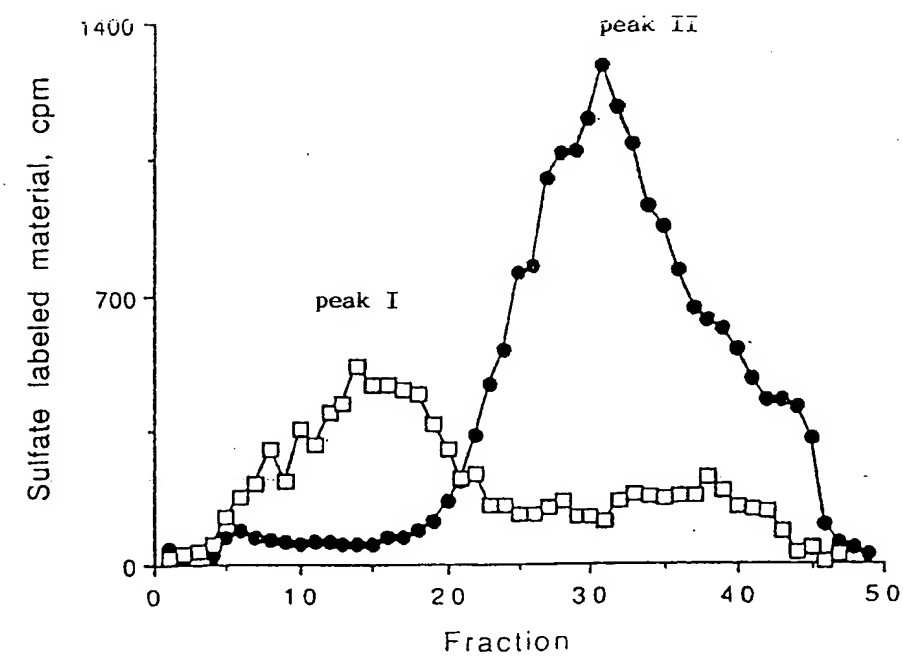

peak I
peak II
Sulfate labelled material, cpm
1600
1200
800
400
0
0
10
20
30
40
50
Fraction

FIG. 6B


peak II
peak I
Sulfate labeled material, cpm
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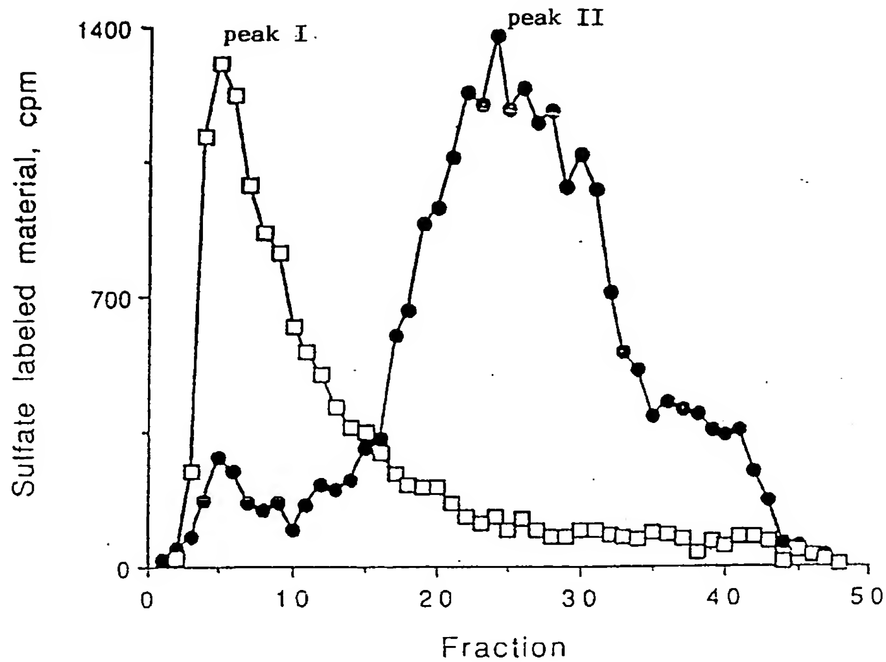
700
0
0
10
20
30
40
50
Fraction

FIG. 7A


peak I
peak II
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700
0
Sulfate labeled material, cpm
0
10
20
30
40
50
Fraction

FIG. 7B

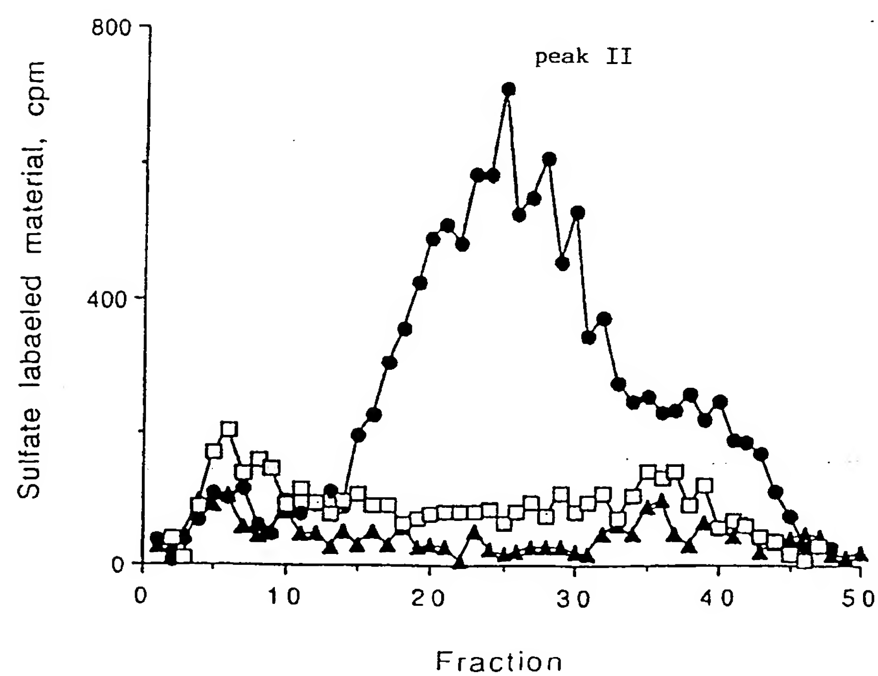
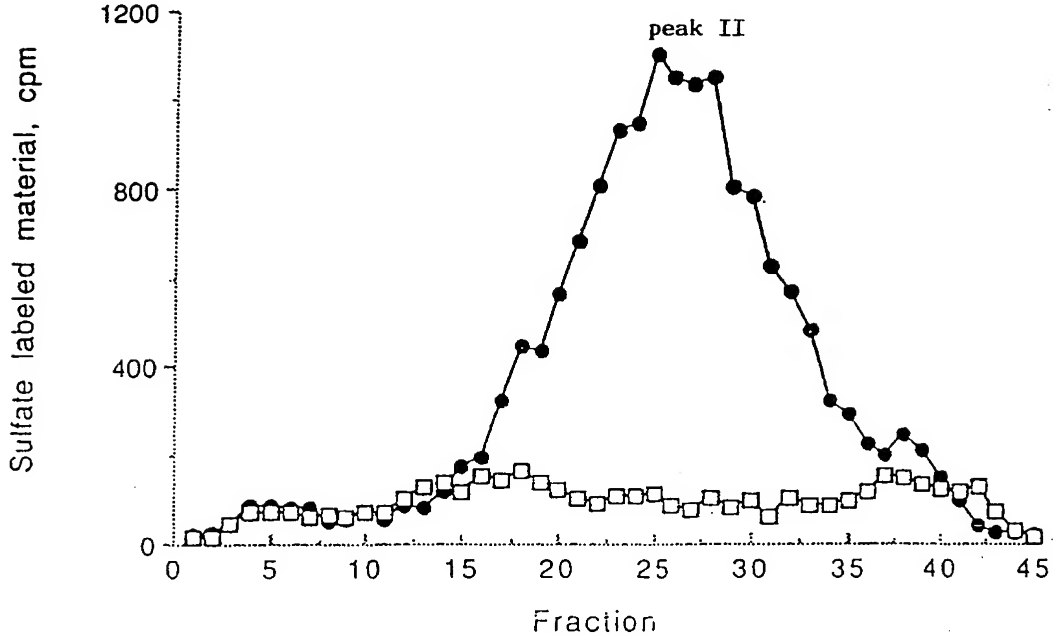

peak II
800
400
0
Sulfate labaeled material, cpm
0
10
20
30
40
50
Fraction

FIG. 8A


peak II
Sulfate labeled material, cpm
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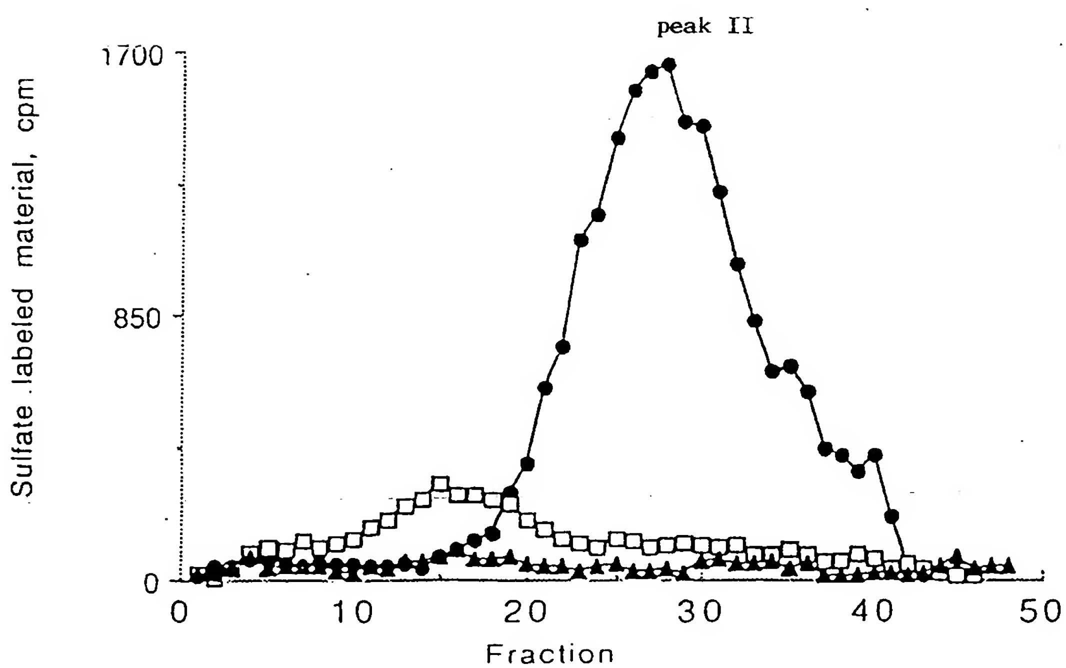
800
400
0
0
5
10
15
20
25
30
35
40
45
Fraction

FIG. 8B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Sulfate labeled material, cpm
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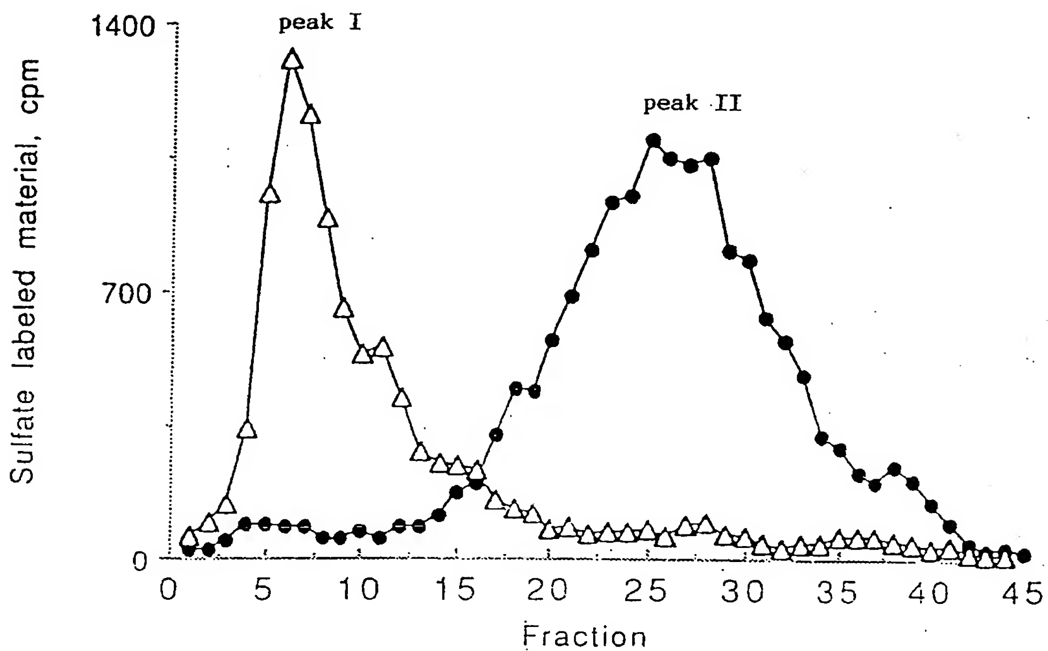
850
0
0
10
20
30
40
50
Fraction

FIG. 9A


peak I
peak II
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700
0
Sulfate labeled material, cpm
0 5 10 15 20 25 30 35 40 45
Fraction

FIG. 9B

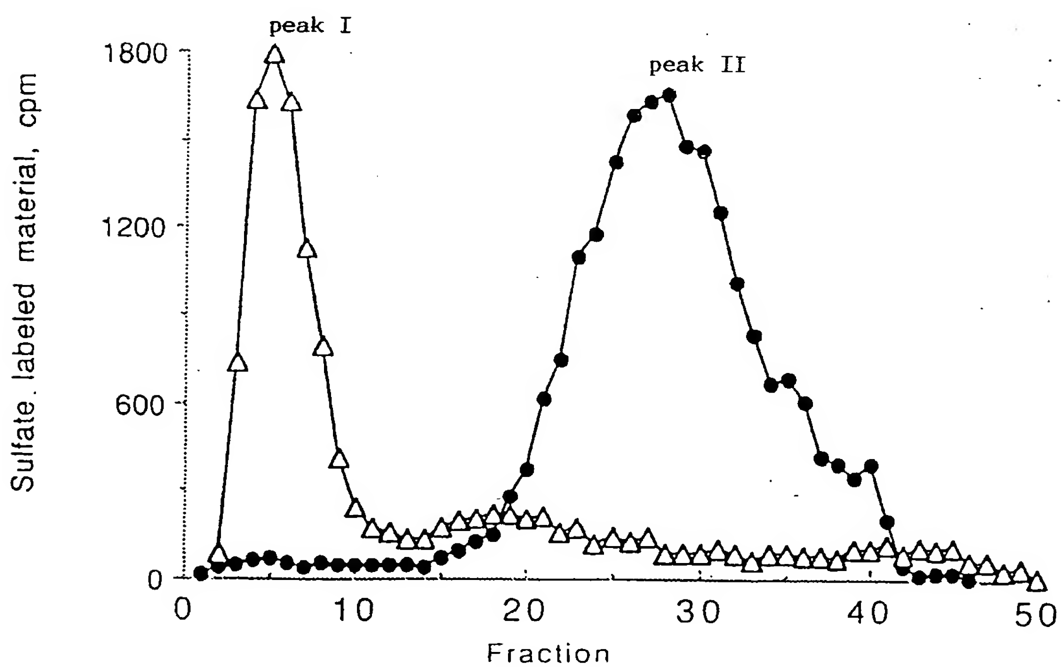
peak I
peak II
1800
1200
600
0
Sulfate labeled material, cpm
0 10 20 30 40 50
Fraction

FIG. 10A

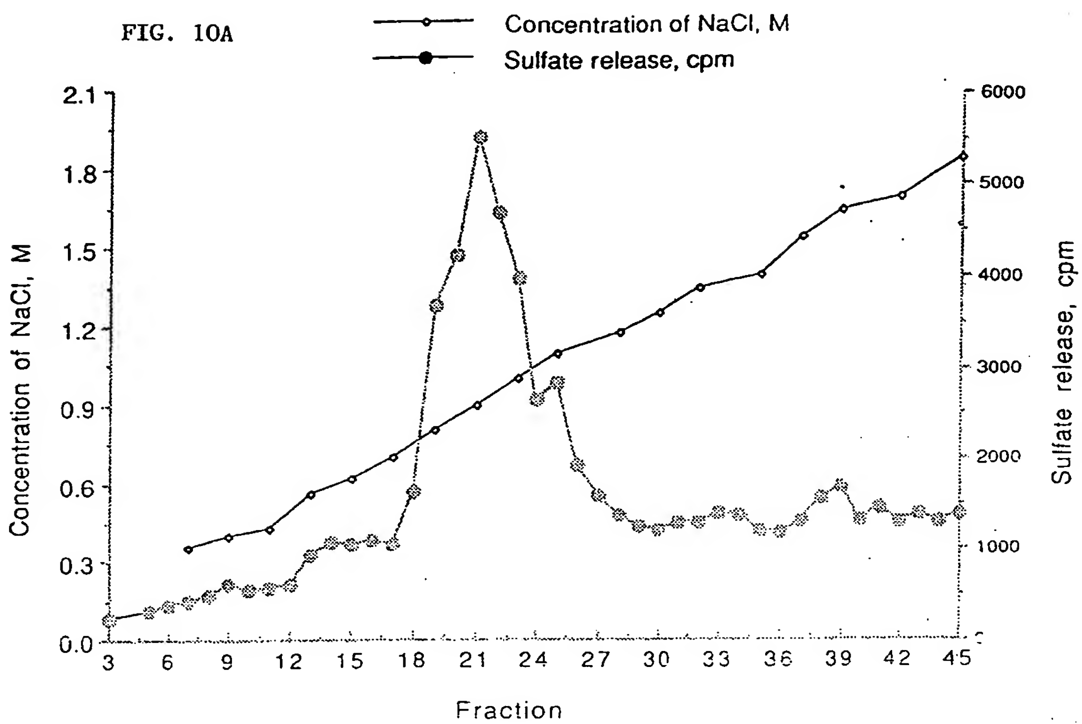

FIG. 10B

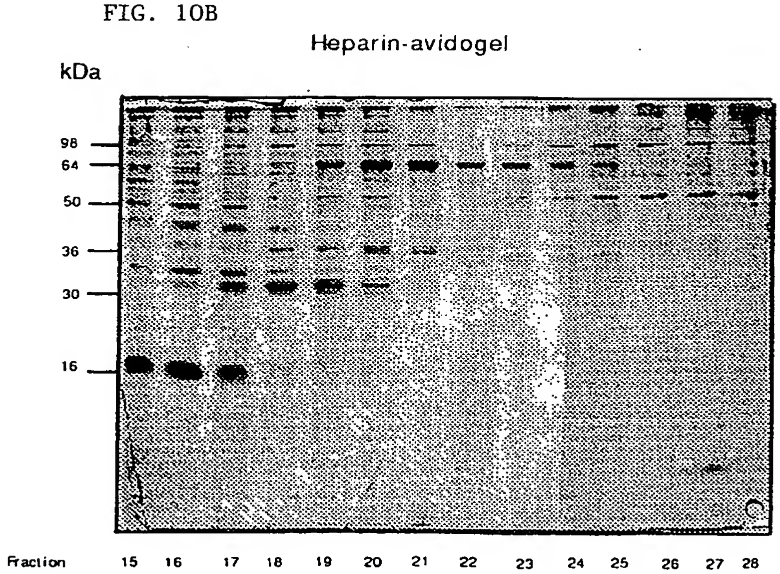

FIG. 11A

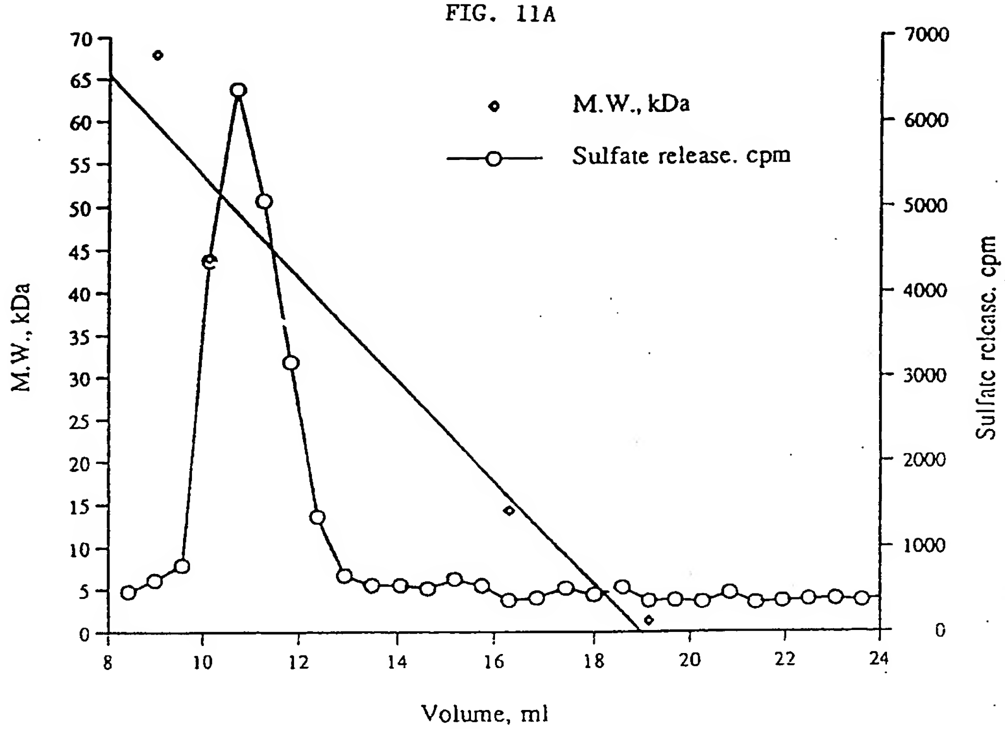

FIG. 11B

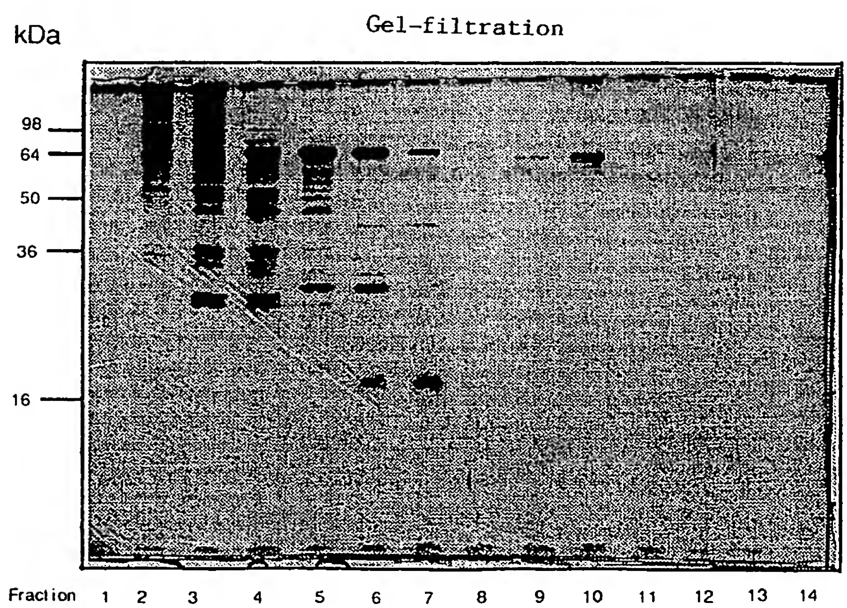

FIG. 12A

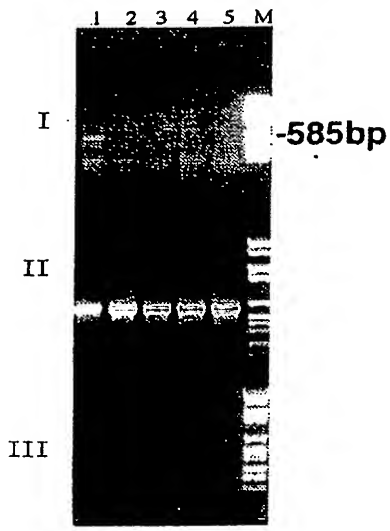

FIG. 12B

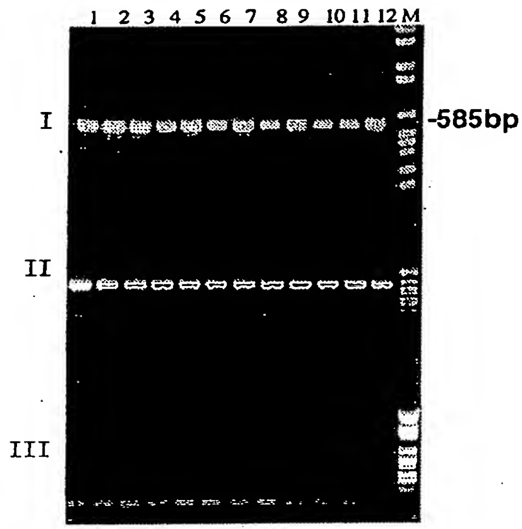

FIG. 12C

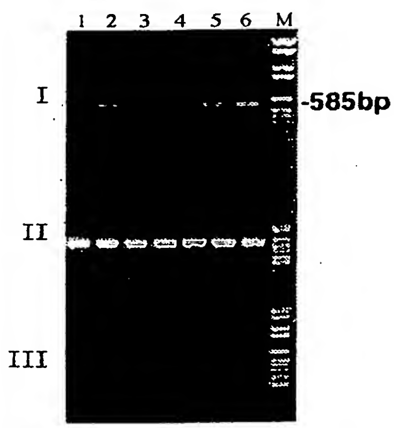

FIG. 12D

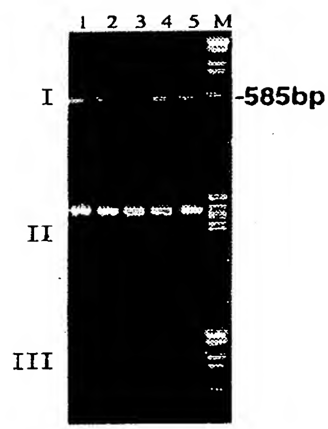

FIG. 12E

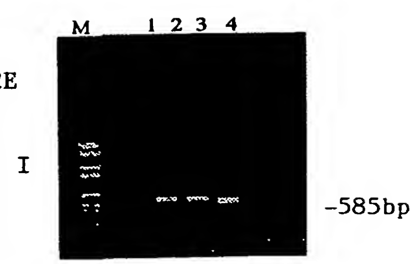

Fig. 13

```
mouse  CTGGCAAGAAGGTCTGGTTGGGAGAGACGAGCTCAGCTTACGGTGGCGGT 50
human  CTGGCAAGAAGGTCTGGTTAGGAGAAACAAGCTCTGCATATGGAGGCGGA 1115

mouse  GCACCCTTGCTGTCCAACACCTTTGCAGCTGGCTTTATGTGGCTGGATAA 100
human  GCGCCCTTGCTATCCGACACCTTTGCAGCTGGCTTTATGTGGCTGGATAA 1165

mouse  ATTGGGCCTGTCAGCCCAGATGGGCATAGAAGTCGTGATGAGGCAGGTGT 150
human  ATTGGGCCTGTCAGCCCGAATGGGAATAGAAGTGGTGATGAGGCAAGTAT 1215

mouse  TCTTCGGAGCAGGCAACTACCACTTAGTGGATGAAAACTTTGAGCCTTTA 200
human  TCTTTGGAGCAGGAAACTACCATTTAGTGGATGAAAACTTCGATCCTTTA 1265

mouse  CCTGATTACTGGCTCTCTCTTCTGTTCAAGAAACTGGTAGGTCCCAGGGT 250
human  CCTGATTATTGGCTATCTCTTCTGTTCAAGAAATTGGTGGGCACCAAGGT 1315

mouse  GTTACTGTCAAGAGTGAAAGGCCCAGACAGGAGCAAACTCCGAGTGTATC 300
human  GTTAATGGCAAGCGTGCAAGGTTCAAAGAGAAGGAAGCTTCGAGTATACC 1365

mouse  TCCACTGCACTAACGTCTATCACCCACGATATCAGGAAGGAGATCTAACT 350
human  TTCATTGCACAAACACTGACAATCCAAGGTATAAAGAAGGAGATTTAACT 1415

mouse  CTGTATGTCCTGAACCTCCATAATGTCACCAAGCACTTGAAGGTACCGCC 400
human  CTGTATGCCATAAACCTCCATAACGTCACCAAGTACTTGCGGTTACCCTA 1465

mouse  TCCGTTGTTCAGGAAACCAGTGGATACGTACCTTCTGAAGCCTTCGGGGC 450
human  TCCTTTTTCTAACAAGCAAGTGGATAAATACCTTCTAAGACCTTTGGGAC 1515

mouse  CGGATGGATTACTTTCCAAATCTGTCCAACTGAACGGTCAAATTCTGAAG 500
human  CTCATGGATTACTTTCCAAATCTGTCCAACTCAATGGTCTAACTCTAAAG 1565

mouse  ATGGTGGATGAGCAGACCCTGCCAGCTTTGACAGAAAAACCTCTCCCCGC 550
human  ATGGTGGATGATCAAACCTTGCCACCTTTAATGGAAAAACCTCTCCGGCC 1615

mouse  AGGAAGTGCACTAAGCCTGCCTGCCTTTTCCTATGGTTTTTTGTCATAA 600
human  AGGAAGTTCACTGGGCTTGCCAGCTTTCTCATATAGTTTTTTGTGATAA 1665

mouse  GAAATGCCAAAATCGCTGCTTGTATATGAAAATAAAA 637
human  GAAATGCCAAAGTTGCTGCTTGCATCTGAAAATAAAA 1702
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FIG. 14

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

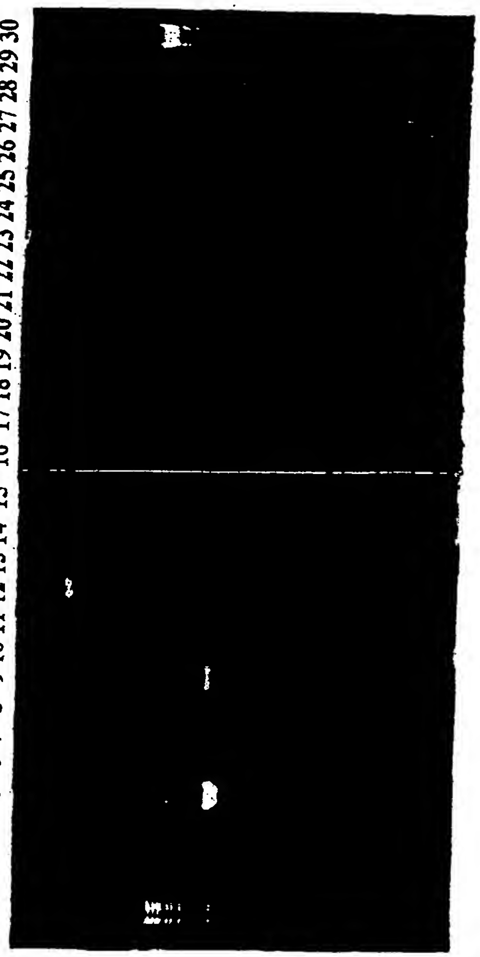

Figure 15

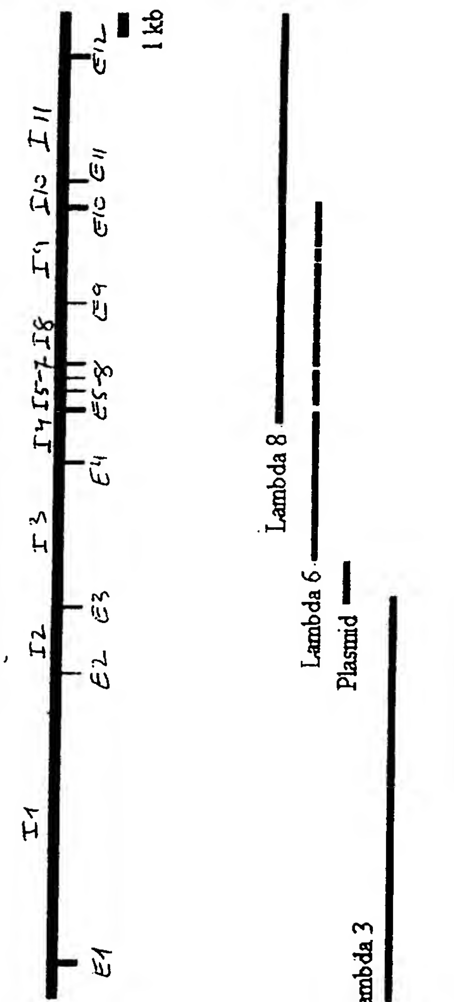
E1
I1
E2
I2
E3
I3
E4
I4
E5-8
I5-7
I8
E9
I9
E10
I10
E11
I11
E12
1 kb
Lambda 8
Lambda 6
Plasmid
Lambda 3

Figure 16

```
ggatcttggctcactgcaatctctgcctcccatgcaattcttatgcatca    50
gcctcctgagtagcttggattataggtctgcgccaccactcctggctaca   100
ccatgttgcccaggctggtcttgaactcttgggctctagtgatccacccg   150
ccttggcctcccaaagtgctgggattacaggtgtgagccatcacacccgg   200
ccccccgtttccatattagtaactcacatgtagacccacaaggatgcacta   250
tttagaaaacttgcaatggtccacttttcaaatcacccaaacatgttaaa   300
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Fig. 16 (continued) 17/34

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 D  V  V  D  L  D  F  F  T  Q  E  P  L  H  L  V  S
CCCCTCGTTCCTGTCCGTCACCATTGACGCCAACCTGGCCACGGACCCGC   2950
  P  S  F  L  S  V  T  I  D  A  N  L  A  T  D  P
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Fig. 16 (continued)

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Fig. 16 (continued)

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Fig. 16 (continued)

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Fig. 16(continued) 21/34

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                                            S  P  K
GCTTCGTACCTTGGCCAGAGGCTTGTCTCCTGCGTACCTGAGGTTTGGTG  15200
  L  R  T  L  A  R  G  L  S  P  A  Y  L  R  F  G
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Fig. 16 (continued)

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G S I P P D V E E K L R L E W P Y
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Q E Q L L L R E H Y Q K K F K N S
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T Y S
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Fig. 16 (continued)

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Fig. 16 (continued)

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Fig. 16 (continued)

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Fig. 16 (continued)

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Fig. 16 (continued)

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Fig. 16 (continued)

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Fig. 16 (continued) 29/34

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Fig. 16 (continued)

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ccactgtgctcggcctaatcttacaagttttcaatatttaaagagtgcta  40850
actttgttgacaatataaaacatatttgagaaaaagagatataagcatct  40900
tatttagaattatgaaaatatcaatagacctacagccgactaaagctttt  40950
cttcataagctcttgcctatattgattcgctcctgtgaatatgcattaat  41000
ttgatttaaataataagtatgtataagaaataacactttccttaatttt   41050
taagaacgttcaacagtttttaatttgaattccaatagtgaaatacatag  41100
aaaatataaaattttctgtagtttagccaaattgtttttgtttcaccaca  41150
gcattctaccaaaatttcttaataacagtaagaaaatgaatgcatacctc  41200
ctgcagggagaggggagttaggcagtttatgggcatagttacaagtgaga  41250
aatttcattggctaccatttacgctaaattcataaaaactgcattcaatt  41300
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aataaaatagccaccattccagaagttgtgtcatgtttatcctttttata  41400
ccaccatcatattgcctattatatagattgtgtgtgttccatttctgta   41450
atgggccagacagtaagtatttctggctttggagtccatatggtctctat  41500
cataactactcatctctgccattgtagcttaaagattatctaggtcaaat  41550
gcctaagtgatatagtgttgaaatacaagttatataatataggctgccac  41600
aaaaaaaaatttatttggtctaaaaaagatttcatgacttttgtagcagc  41650
atgggtggggcatgcaccacttggttaactcggtgtatctttctcctttg  41700
cagATCTGTCCAACTCAATGGTCTAACTCTAAAGATGGTGGATGATCAAA  41750
    S  V  Q  L  N  G  L  T  L  K  M  V  D  D  Q

CCTTGCCACCTTTAATGGAAAAACCTCTCCGGCCAGGAAGTTCACTGGGC  41800
T  L  P  P  L  M  E  K  P  L  R  P  G  S  S  L  G

TTGCCAGCTTTCTCATATAGTTTTTTTGTGATAAGAAATGCCAAAGTTGC  41850
 L  P  A  F  S  Y  S  F  F  V  I  R  N  A  K  V  A

TGCTTGCATCTGAAAATAAAATATACTAGTCCTGACACTGaatttttcaa  41900
  A  C  I  *
gtatactaagagtaaagcaactcaagttataggaaaggaagcagatacct  41950
tgcaaagcaactagtgggtgcttgagagacactgggacactgtcagtgct  42000
agatttagcacagtattttgatctcgctaggtagaacactgctaataata  42050
atagctaataataccttgttccaaatactgcttagcattttgcatgtttt  42100
acttttatctaaagttttgttttgttttattatttatttatttatttatt  42150
ttgagacagaatctctctctgtcacccaggctggagtgccatggtgcgat  42200
cttggctcactgcaactttaagcaattctcctgcctcagcttcctgagta  42250
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atcactgcagccttttaactcctgggctcaagtcatcctcctgcttagcc  42550
tcccaagtagctaggaccacagacacatgccatcacacttggctattttt  42600
aaaaaatttttgtagagatggggtctcgctatgttacccaaactggtcc   42650
tgaactcctggactcaattgatcctcccaccttggccttccaggtgctgg  42700
gatttctttgggagtacagcatggtacagcaggagatcatttgatgttac  42750
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acagagagagattccatctcaaaaaaacaagttattaaaaatgtatatga  43150
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ttttagaattctttccttcatgtgccatctctacaggcacccatcagaaa  43300
aagcatactgccgttaccgtgaaactggttgtaaaagagaaactatctat  43350
ttgcaccttaaaagacagctagattttgctgattttcttctttcggtttt  43400
```

Fig. 16 (continued)

```
ctttgtcagcaataatatgtgagaggacagattgttagatatgatagtat  43450
aaaaaatggttaatgacaattcagaggcgaggagattctgtaaacttaaa  43500
attactataaatgaaattgatttgtcaagaggataaattttagaaaacac  43550
ccaataccttataactgtctgttaatgcttgctttttctctacctttctt  43600
ccttgtttcagttgggaagcttttggctgcaagtaacagaaactcctaat  43650
tcaaatggcttaagcaataaggaaatgtatattcccacataactagacgt  43700
tcaaacaggccaggctccagcacttcagtacgtcaccagggatctgggtt  43750
cttcccagctctctgctctgccatctttagcgctggcttcattctcagac  43800
tctggtagcatgatggctgtagctgtttcatgggccccttcaaacctcat  43850
agcaaccagaggaagaaaatgagccatttttttgagtctccttcatagact  43900
tgaataactctttttcagagcttctcacagcaaacctctcctcatgtctc  43950
ctcatgtcttattgttcagaaatgggtaatgtggccatttcaccagtcac  44000
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tggagagggtgttggtcagtctacaaactgaacactgcagttctgcgctt  44100
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ttcaaatgtatgcctgttatggatatagtatctttaaaatttttttatttt  44200
aatagctttaggggtacacacttttttgcttacaggggtgaattgtgtagt  44250
ggtgaagactcggcttttaatgtacttgtcacctgagtgatgtacattgt  44300
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ctgagtctccaacatcccttataccactgtgtatgttcttgtgtacctac  44400
agctaagcttccacttataagtgagaacatgcagtatttggttttccatt  44450
cctgagttacttcccttaggataacagccccccagttccgtccaagttgct  44500
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tataccacattttctttatccacttatcagttgatggacacttaggttaa  44600
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tttttatattttcacatttgaaataaagtaatttttataaccttgatatt  44750
gtatgactattcttttagtaatgtaaagcctacagactcctacatttgga  44800
accactagtgtgttgtttcacccccttgttatactatcaggatcctcga  44898
```

Figure 17

```
                                                                        50
human   MLLRSKPALP PPLMLLLLGP LGPLSPGALP RPAQAQDVVD LDFFTQEPLH
mouse   ~~~~~~~~ML RLLLLWLWGP LGALAQGAPA GTAPTDDVVD LEFYTKRPLR
rat     ~~~~~~~~~~ ~LLLLWLWGR LRALTQGTPA GTAPTKDVVD LEFYTKRLFQ

                                                                       100
human   LVSPSFLSVT IDANLATDPR FLILLGSPKL RTLARGLSPA YLRFGGTKTD
mouse   SVSPSFLSIT IDASLATDPR FLTFLGSPRL RALARGLSPA YLRFGGTKTD
rat     SVSPSFLSIT IDASLATDPR FLTFLSSPRL RALSRGLSPA YLRFGGTKTD

                                                                       150
human   FLIFDPKKES TFEERSYWQS QVNQDICKYG SIPPDVEEKL RLEWPYQEQL
mouse   FLIFDPDKEP TSEERSYWKS QVNHDICRSE PVSAAVLRKL QVEWPFQELL
rat     FLIFDPNNEP TSEERSYWQS QDNNDICGSD RVSADVL~~~ ~~~~~~~~~~

                                                                       200
human   LLREHYQKKF KNSTYSRSSV DVLYTFANCS GLDLIFGLNA LLRTADLQWN
mouse   LLREQYQKEF KNSTYSRSSV DMLYSFAKCS GLDLIFGLNA LLRTPDLRWN
rat     ~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~

                                                                       250
human   SSNAQLLLDY CSSKGYNISW ELGNEPNSFL KKADIFINGS QLGEDYIQLH
mouse   SSNAQLLLDY CSSKGYNISW ELGNEPNSFW KKAHILIDGL QLGEDFVELH
rat     ~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~

                                                                       300
human   KLLRKSTFKN AKLYGPDVGQ PRRKTAKMLK SFLKAGGEVI DSVTWHHYYL
mouse   KLLQRSAFQN AKLYGPDIGQ PRGKTVKLLR SFLKAGGEVI DSLTWHHYYL
rat     ~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~

                                                                       350
human   NGRTATREDF LNPDVLDIFI SSVQKVFQVV ESTRPGKKVW LGETSSAYGG
mouse   NGRIATKEDF LSSDALDTFI LSVQKILKVT KEITPGKKVW LGETSSAYGG
rat     ~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~

                                                                       400
human   GAPLLSDTFA AGFMWLDKLG LSARMGIEVV MRQVFFGAGN YHLVDENFDP
mouse   GAPLLSNTFA AGFMWLDKLG LSAQMGIEVV MRQVFFGAGN YHLVDENFEP
rat     ~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~

                                                                       450
human   LPDYWLSLLF KKLVGTKVLM ASVQGSKRRK LRVYLHCTNT DNPRYKEGDL
mouse   LPDYWLSLLF KKLVGPRVLL SRVKGPDRSK LRVYLHCTNV YHPRYQEGDL
rat     ~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~

                                                                       500
human   TLYAINLHNV TKYLRLPYPF SNKQVDKYLL RPLGPHGLLS KSVQLNGLTL
mouse   TLYVLNLHNV TKHLKVPPPL FRKPVDTYLL KPSGPDGLLS KSVQLNGQIL
rat     ~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~L

                                                           543
human   KMVDDQTLPP LMEKPLRPGS SLGLPAFSYS FFVIRNAKVA ACI~
mouse   KMVDEQTLPA LTEKPLPAGS ALSLPAFSYG FFVIRNAKIA ACI~
rat     KMVDEQTXPA LTEKPLPAGS SLSVPAFSYG FFVIRNAKIA ACI~
```

Figure 18

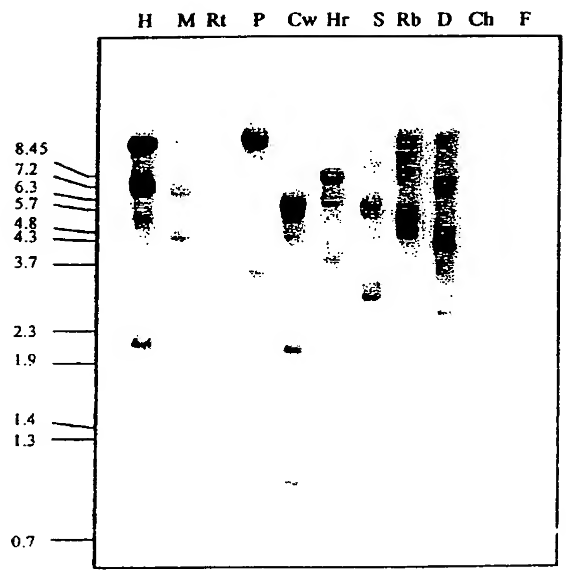

Figure 19

```
    |MLLRSKPALPPPLMLLLLGPLGPLSPGALPRPAQAQDVVDLDFFTQEPLHLVSPSFLSVT|  60
PHD |             EEEEE                 HHH         EEEE      EEE|

    |IDANLATDPRFLILLGSPKLRTLARGLSPAYLRFGGTKTDFLIFDPKKESTFEERSYWQS| 120
PHD |EEE       EEEEE    HHHHHH   HHHHE     EEEEE           HHHHHH|

    |QVNQDICKYGSIPPDVEEKLRLEWPYQEQLLLREHYQKKFKNSTYSRSSVDVLYTFANCS| 180
PHD |HHHHHHHH      HHHHHHH  HHHHHHHHHHHHHHHH     EEEEEEEEEEEE    |

    |GLDLIFGLNALLRTADLQWNSSNAQLLLDYCSSKGYNISWELGNEPNSFLKKADIFINGS| 240
PHD |   HHHHHHHHHHHHHHHHHHHHHHHHHHHHH    EEEEE     HHHHHHH EEEE  |

    |QLGEDYIQLHKLLRKSTFKNAKLYGPDVGQPRRKTAKMLKSFLKAGGEVIDSVTWHHYYL| 300
PHD |    HHHHHHHHHHHHHHHHH           HHHHHHHHHHHHH   EEEEEEEEEEE |

    |NGRTATREDFLNPDVLDIFISSVQKVFQVVESTRPGKKVWLGETSSAYGGGAPLLSDTFA| 360
PHD |              HHHHHHHHHHHEEEEEEE     EEEEEE          HHHHHHH|

    |AGFMWLDKLGLSARMGIEVVMRQVFFGAGNYHLVDENFDPLPDYWLSLLFKKLVGTKVLM| 420
PHD |HHHHHHHH    HHHH HHHHHHHHHHH  EEEEE      HHHHHHHHHHHH  EEEEE|

    |ASVQGSKRRKLRVYLHCTNTDNPRYKEGDLTLYAINLHNVTKYLRLPYPFSNKQVDKYLL| 480
PHD |EEE     E EEEEEEEE           EEEEEE      EEEEE      HHHHHHHH|

    |RPLGPHGLLSKSVQLNGLTLKMVDDQTLPPLMEKPLRPGSSLGLPAFSYSFFVIRNAKVA| 540
PHD |HH      EEEEEEE   EEEEE                         EEEEEEEE EE |

    |ACI|                                                           543
PHD |   |
```

SEQUENCE LISTING

(1) GENERAL INFORMATION:

(i) APPLICANT: Iris Pecker, Israel Vlodavsky and Elena Feinstein

(ii) TITLE OF INVENTION: POLYNUCLEOTIDE ENCODING A POLYPEPTIDE HAVING HEPARANASE ACTIVITY AND EXPRESSION OF SAME IN GENETICALLY MODIFIED CELLS

(iii) NUMBER OF SEQUENCES: 47

(iv) CORRESPONDENCE ADDRESS:

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(C) CITY: Arlington
(D) STATE: Virginia
(E) COUNTRY: United States of America
(F) ZIP: 22202

(v) COMPUTER READABLE FORM:

(A) MEDIUM TYPE: 1.44 megabyte, 3.5" microdisk
(B) COMPUTER: Twinhead* Slimnote-890TX
(C) OPERATING SYSTEM: MS DOS version 6.2, Windows version 3.11
(D) SOFTWARE: Word for Windows version 2.0 converted to an ASCI file

(vi) CURRENT APPLICATION DATA:

(A) APPLICATION NUMBER:
(B) FILING DATE:
(C) CLASSIFICATION:

(vii) PRIOR APPLICATION DATA:

(A) APPLICATION NUMBER: 08/922,170
(B) FILING DATE: 2 SEP 1997
(A) APPLICATION NUMBER: 09/109,386
(B) FILING DATE: 10 JUL 1998
(A) APPLICATION NUMBER: PCT/US98/17954
(B) FILING DATE: 31 AUG 1998
(A) APPLICATION NUMBER: 09/258,892
(B) FILING DATE: 1 MAR 1999

(viii) ATTORNEY/AGENT INFORMATION:

(A) NAME: Friedmam, Mark M.
(B) REGISTRATION NUMBER: 33,883
(C) REFERENCE/DOCKET NUMBER: 910/62

(ix) TELECOMMUNICATION INFORMATION:

(A) TELEPHONE: 972-3-5625553
(B) TELEFAX: 972-3-5625554
(C) TELEX:

(2) INFORMATION FOR SEQ ID NO:1:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 27
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

CCATCCTAAT ACGACTCACT ATAGGGC 27

(2) INFORMATION FOR SEQ ID NO:2:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 24
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single

(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:
GTAGTGATGC CATGTAACTG AATC 24

(2) INFORMATION FOR SEQ ID NO:3:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 23
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:
ACTCACTATA GGGCTCGAGC GGC 23

(2) INFORMATION FOR SEQ ID NO:4:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 22
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:
GCATCTTAGC CGTCTTTCTT CG 22

(2) INFORMATION FOR SEQ ID NO:5:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 15
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:
TTTTTTTTTT TTTTT 15

(2) INFORMATION FOR SEQ ID NO:6:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 23
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:6:
TTCGATCCCA AGAAGGAATC AAC 23

(2) INFORMATION FOR SEQ ID NO:7:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 24
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:7:
GTAGTGATGC CATGTAACTG AATC 24

(2) INFORMATION FOR SEQ ID NO:8:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 9
(B) TYPE: amino acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:8:
Tyr Gly Pro Asp Val Gly Gln Pro Arg

5 9

(2) INFORMATION FOR SEQ ID NO:9:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 1721

(B) TYPE: nucleic acid

(C) STRANDEDNESS: double

(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:9:

CTAGAGCTTT CGACTCTCCG CTGCGCGGCA GCTGGCGGGG GGAGCAGCCA GGTGAGCCCA 60
AGATGCTGCT GCGCTCGAAG CCTGCGCTGC CGCCGCCGCT GATGCTGCTG CTCCTGGGGC 120
CGCTGGGTCC CCTCTCCCCT GGCGCCCTGC CCCGACCTGC GCAAGCACAG GACGTCGTGG 180
ACCTGGACTT cTTCACCCAG GAGCCGCTGC ACCTGGTGAG CCCCTCGTTC CTGTCCGTCA 240
CCATTGACGC CAACCTGGCC ACGGACCCGC GGTTCCTCAT CCTCCTGGGT TCTCCAAAGC 300
TTCGTACCTT GGCCAGAGGC TTGTCTCCTG CGTACCTGAG GTTTGGTGGC ACCAAGACAG 360
ACTTCCTAAT TTTCGATCCC AAGAAGGAAT CAACCTTTGA AGAGAGAAGT TACTGGCAAT 420
CTCAAGTCAA CCAGGATATT TGCAAATATG GATCCATCCC TCCTGATGTG GAGGAGAAGT 480
TACGGTTGGA ATGGCCCTAC CAGGAGCAAT TGCTACTCCG AGAACACTAC CAGAAAAAGT 540
TCAAGAACAG CACCTACTCA AGAAGCTCTG TAGATGTGCT ATACACTTTT GCAAACTGCT 600
CAGGACTGGA CTTGATCTTT GGCCTAAATG CGTTATTAAG AACAGCAGAT TTGCAGTGGA 660
ACAGTTCTAA TGCTCAGTTG CTCCTGGACT ACTGCTCTTC CAAGGGGTAT AACATTTCTT 720
GGGAACTAGG CAATGAACCT AACAGTTTCC TTAAGAAGGC TGATATTTTC ATCAATGGGT 780
CGCAGTTAGG AGAAGATTAT ATTCAATTGC ATAAACTTCT AAGAAAGTCC ACCTTCAAAA 840
ATGCAAAACT CTATGGTCCT GATGTTGGTC AGCCTCGAAG AAAGACGGCT AAGATGCTGA 900
AGAGCTTCCT GAAGGCTGGT GGAGAAGTGA TTGATTCAGT TACATGGCAT CACTACTATT 960
TGAATGGACG GACTGCTACC AGGGAAGATT TTCTAAACCC TGATGTATTG GACATTTTTA 1020
TTTCATCTGT GCAAAAAGTT TTCCAGGTGG TTGAGAGCAC CAGGCCTGGC AAGAAGGTCT 1080
GGTTAGGAGA AACAAGCTCT GCATATGGAG GCGGAGCGCC CTTGCTATCC GACACCTTTG 1140
CAGCTGGCTT TATGTGGCTG GATAAATTGG GCCTGTCAGC CCGAATGGGA ATAGAAGTGG 1200
TGATGAGGCA AGTATTCTTT GGAGCAGGAA ACTACCATTT AGTGGATGAA AACTTCGATC 1260
CTTTACCTGA TTATTGGCTA TCTCTTCTGT TCAAGAAATT GGTGGGCACC AAGGTGTTAA 1320
TGGCAAGCGT GCAAGGTTCA AAGAGAAGGA AGCTTCGAGT ATACCTTCAT TGCACAAACA 1380
CTGACAATCC AAGGTATAAA GAAGGAGATT TAACTCTGTA TGCCATAAAC CTCCATAACG 1440
TCACCAAGTA CTTGCGGTTA CCCTATCCTT TTTCTAACAA GCAAGTGGAT AAATACCTTC 1500
TAAGACCTTT GGGACCTCAT GGATTACTTT CCAAATCTGT CCAACTCAAT GGTCTAACTC 1560
TAAAGATGGT GGATGATCAA ACCTTGCCAC CTTTAATGGA AAAACCTCTC CGGCCAGGAA 1620
GTTCACTGGG CTTGCCAGCT TTCTCATATA GTTTTTTTGT GATAAGAAAT GCCAAAGTTG 1680
CTGCTTGCAT CTGAAAATAA AATATACTAG TCCTGACACT G 1721

(2) INFORMATION FOR SEQ ID NO:10:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 543

(B) TYPE: amino acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:10:

Met Leu Leu Arg Ser Lys Pro Ala Leu Pro Pro Pro Leu Met Leu Leu
5 10 15

Leu Leu Gly Pro Leu Gly Pro Leu Ser Pro Gly Ala Leu Pro Arg Pro
20 25 30

Ala Gln Ala Gln Asp Val Val Asp Leu Asp Phe Phe Thr Gln Glu Pro
35 40 45

Leu His Leu Val Ser Pro Ser Phe Leu Ser Val Thr Ile Asp Ala Asn
50 55 60

Leu Ala Thr Asp Pro Arg Phe Leu Ile Leu Leu Gly Ser Pro Lys Leu
65 70 75 80

Arg Thr Leu Ala Arg Gly Leu Ser Pro Ala Tyr Leu Arg Phe Gly Gly
85 90 95

Thr Lys Thr Asp Phe Leu Ile Phe Asp Pro Lys Lys Glu Ser Thr Phe
100 105 110

Glu Glu Arg Ser Tyr Trp Gln Ser Gln Val Asn Gln Asp Ile Cys Lys
115 120 125

Tyr Gly Ser Ile Pro Pro Asp Val Glu Glu Lys Leu Arg Leu Glu Trp
130 135 140

Pro Tyr Gln Glu Gln Leu Leu Leu Arg Glu His Tyr Gln Lys Lys Phe
145 150 155 160

Lys Asn Ser Thr Tyr Ser Arg Ser Ser Val Asp Val Leu Tyr Thr Phe
165 170 175

Ala Asn Cys Ser Gly Leu Asp Leu Ile Phe Gly Leu Asn Ala Leu Leu
180 185 190

Arg Thr Ala Asp Leu Gln Trp Asn Ser Ser Asn Ala Gln Leu Leu Leu
195 200 205

Asp Tyr Cys Ser Ser Lys Gly Tyr Asn Ile Ser Trp Glu Leu Gly Asn
210 215 220

Glu Pro Asn Ser Phe Leu Lys Lys Ala Asp Ile Phe Ile Asn Gly Ser
225 230 235 240

Gln Leu Gly Glu Asp Tyr Ile Gln Leu His Lys Leu Leu Arg Lys Ser
245 250 255

Thr Phe Lys Asn Ala Lys Leu Tyr Gly Pro Asp Val Gly Gln Pro Arg
260 265 270

Arg Lys Thr Ala Lys Met Leu Lys Ser Phe Leu Lys Ala Gly Gly Glu
275 280 285

Val Ile Asp Ser Val Thr Trp His His Tyr Tyr Leu Asn Gly Arg Thr
290 295 300

Ala Thr Arg Glu Asp Phe Leu Asn Pro Asp Val Leu Asp Ile Phe Ile
305 310 315 320

Ser Ser Val Gln Lys Val Phe Gln Val Val Glu Ser Thr Arg Pro Gly
325 330 335

Lys Lys Val Trp Leu Gly Glu Thr Ser Ser Ala Tyr Gly Gly Gly Ala
340 345 350

Pro Leu Leu Ser Asp Thr Phe Ala Ala Gly Phe Met Trp Leu Asp Lys
355 360 365

Leu Gly Leu Ser Ala Arg Met Gly Ile Glu Val Val Met Arg Gln Val
370 375 380

Phe Phe Gly Ala Gly Asn Tyr His Leu Val Asp Glu Asn Phe Asp Pro
385 390 395 400

Leu Pro Asp Tyr Trp Leu Ser Leu Leu Phe Lys Lys Leu Val Gly Thr
405 410 415

Lys Val Leu Met Ala Ser Val Gln Gly Ser Lys Arg Arg Lys Leu Arg
420 425 430

Val Tyr Leu His Cys Thr Asn Thr Asp Asn Pro Arg Tyr Lys Glu Gly
435 440 445

Asp Leu Thr Leu Tyr Ala Ile Asn Leu His Asn Val Thr Lys Tyr Leu
450 455 460

Arg Leu Pro Tyr Pro Phe Ser Asn Lys Gln Val Asp Lys Tyr Leu Leu
465 470 475 480

Arg Pro Leu Gly Pro His Gly Leu Leu Ser Lys Ser Val Gln Leu Asn
485 490 495

Gly Leu Thr Leu Lys Met Val Asp Asp Gln Thr Leu Pro Pro Leu Met
500 505 510

Glu Lys Pro Leu Arg Pro Gly Ser Ser Leu Gly Leu Pro Ala Phe Ser
515 520 525

Tyr Ser Phe Phe Val Ile Arg Asn Ala Lys Val Ala Ala Cys Ile
530 535 540 543

(2) INFORMATION FOR SEQ ID NO:11:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 1721

(B) TYPE: nucleic acid

(C) STRANDEDNESS: double

(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:11:

CT AGA GCT TTC GAC 14

TCT CCG CTG CGC GGC AGC TGG CGG GGG GAG CAG CCA GGT GAG CCC AAG 62

ATG CTG CTG CGC TCG AAG CCT GCG CTG CCG CCG CCG CTG ATG CTG CTG 110
Met Leu Leu Arg Ser Lys Pro Ala Leu Pro Pro Pro Leu Met Leu Leu
5 10 15

CTC CTG GGG CCG CTG GGT CCC CTC TCC CCT GGC GCC CTG CCC CGA CCT 158
Leu Leu Gly Pro Leu Gly Pro Leu Ser Pro Gly Ala Leu Pro Arg Pro
20 25 30

GCG CAA GCA CAG GAC GTC GTG GAC CTG GAC TTC TTC ACC CAG GAG CCG 206
Ala Gln Ala Gln Asp Val Val Asp Leu Asp Phe Phe Thr Gln Glu Pro
35 40 45

CTG CAC CTG GTG AGC CCC TCG TTC CTG TCC GTC ACC ATT GAC GCC AAC 254
Leu His Leu Val Ser Pro Ser Phe Leu Ser Val Thr Ile Asp Ala Asn
50 55 60

CTG GCC ACG GAC CCG CGG TTC CTC ATC CTC CTG GGT TCT CCA AAG CTT 302
Leu Ala Thr Asp Pro Arg Phe Leu Ile Leu Leu Gly Ser Pro Lys Leu
65 70 75 80

CGT ACC TTG GCC AGA GGC TTG TCT CCT GCG TAC CTG AGG TTT GGT GGC 350
Arg Thr Leu Ala Arg Gly Leu Ser Pro Ala Tyr Leu Arg Phe Gly Gly
85 90 95

ACC AAG ACA GAC TTC CTA ATT TTC GAT CCC AAG AAG GAA TCA ACC TTT 398
Thr Lys Thr Asp Phe Leu Ile Phe Asp Pro Lys Lys Glu Ser Thr Phe
100 105 110

GAA GAG AGA AGT TAC TGG CAA TCT CAA GTC AAC CAG GAT ATT TGC AAA 446
Glu Glu Arg Ser Tyr Trp Gln Ser Gln Val Asn Gln Asp Ile Cys Lys
115 120 125

TAT GGA TCC ATC CCT CCT GAT GTG GAG GAG AAG TTA CGG TTG GAA TGG 494
Tyr Gly Ser Ile Pro Pro Asp Val Glu Glu Lys Leu Arg Leu Glu Trp
130 135 140

CCC TAC CAG GAG CAA TTG CTA CTC CGA GAA CAC TAC CAG AAA AAG TTC 542
Pro Tyr Gln Glu Gln Leu Leu Leu Arg Glu His Tyr Gln Lys Lys Phe
145 150 155 160

AAG AAC AGC ACC TAC TCA AGA AGC TCT GTA GAT GTG CTA TAC ACT TTT 590
Lys Asn Ser Thr Tyr Ser Arg Ser Ser Val Asp Val Leu Tyr Thr Phe
165 170 175

GCA AAC TGC TCA GGA CTG GAC TTG ATC TTT GGC CTA AAT GCG TTA TTA 638
Ala Asn Cys Ser Gly Leu Asp Leu Ile Phe Gly Leu Asn Ala Leu Leu
180 185 190

AGA ACA GCA GAT TTG CAG TGG AAC AGT TCT AAT GCT CAG TTG CTC CTG 686
Arg Thr Ala Asp Leu Gln Trp Asn Ser Ser Asn Ala Gln Leu Leu Leu
195 200 205

GAC TAC TGC TCT TCC AAG GGG TAT AAC ATT TCT TGG GAA CTA GGC AAT 734
Asp Tyr Cys Ser Ser Lys Gly Tyr Asn Ile Ser Trp Glu Leu Gly Asn
210 215 220

GAA CCT AAC AGT TTC CTT AAG AAG GCT GAT ATT TTC ATC AAT GGG TCG 782
Glu Pro Asn Ser Phe Leu Lys Lys Ala Asp Ile Phe Ile Asn Gly Ser
225 230 235 240

CAG TTA GGA GAA GAT TAT ATT CAA TTG CAT AAA CTT CTA AGA AAG TCC 830
Gln Leu Gly Glu Asp Tyr Ile Gln Leu His Lys Leu Leu Arg Lys Ser
245 250 255

ACC TTC AAA AAT GCA AAA CTC TAT GGT CCT GAT GTT GGT CAG CCT CGA 878
Thr Phe Lys Asn Ala Lys Leu Tyr Gly Pro Asp Val Gly Gln Pro Arg
260 265 270

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AGA AAG ACG GCT AAG ATG CTG AAG AGC TTC CTG AAG GCT GGT GGA GAA  926
Arg Lys Thr Ala Lys Met Leu Lys Ser Phe Leu Lys Ala Gly Gly Glu
        275                 280                 285

GTG ATT GAT TCA GTT ACA TGG CAT CAC TAC TAT TTG AAT GGA CGG ACT  974
Val Ile Asp Ser Val Thr Trp His His Tyr Tyr Leu Asn Gly Arg Thr
    290                 295                 300

GCT ACC AGG GAA GAT TTT CTA AAC CCT GAT GTA TTG GAC ATT TTT ATT 1022
Ala Thr Arg Glu Asp Phe Leu Asn Pro Asp Val Leu Asp Ile Phe Ile
305                 310                 315                 320

TCA TCT GTG CAA AAA GTT TTC CAG GTG GTT GAG AGC ACC AGG CCT GGC 1070
Ser Ser Val Gln Lys Val Phe Gln Val Val Glu Ser Thr Arg Pro Gly
                325                 330                 335

AAG AAG GTC TGG TTA GGA GAA ACA AGC TCT GCA TAT GGA GGC GGA GCG 1118
Lys Lys Val Trp Leu Gly Glu Thr Ser Ser Ala Tyr Gly Gly Gly Ala
            340                 345                 350

CCC TTG CTA TCC GAC ACC TTT GCA GCT GGC TTT ATG TGG CTG GAT AAA 1166
Pro Leu Leu Ser Asp Thr Phe Ala Ala Gly Phe Met Trp Leu Asp Lys
        355                 360                 365

TTG GGC CTG TCA GCC CGA ATG GGA ATA GAA GTG GTG ATG AGG CAA GTA 1214
Leu Gly Leu Ser Ala Arg Met Gly Ile Glu Val Val Met Arg Gln Val
    370                 375                 380

TTC TTT GGA GCA GGA AAC TAC CAT TTA GTG GAT GAA AAC TTC GAT CCT 1262
Phe Phe Gly Ala Gly Asn Tyr His Leu Val Asp Glu Asn Phe Asp Pro
385                 390                 395                 400

TTA CCT GAT TAT TGG CTA TCT CTT CTG TTC AAG AAA TTG GTG GGC ACC 1310
Leu Pro Asp Tyr Trp Leu Ser Leu Leu Phe Lys Lys Leu Val Gly Thr
                405                 410                 415

AAG GTG TTA ATG GCA AGC GTG CAA GGT TCA AAG AGA AGG AAG CTT CGA 1358
Lys Val Leu Met Ala Ser Val Gln Gly Ser Lys Arg Arg Lys Leu Arg
            420                 425                 430

GTA TAC CTT CAT TGC ACA AAC ACT GAC AAT CCA AGG TAT AAA GAA GGA 1406
Val Tyr Leu His Cys Thr Asn Thr Asp Asn Pro Arg Tyr Lys Glu Gly
        435                 440                 445

GAT TTA ACT CTG TAT GCC ATA AAC CTC CAT AAC GTC ACC AAG TAC TTG 1454
Asp Leu Thr Leu Tyr Ala Ile Asn Leu His Asn Val Thr Lys Tyr Leu
    450                 455                 460

CGG TTA CCC TAT CCT TTT TCT AAC AAG CAA GTG GAT AAA TAC CTT CTA 1502
Arg Leu Pro Tyr Pro Phe Ser Asn Lys Gln Val Asp Lys Tyr Leu Leu
465                 470                 475                 480

AGA CCT TTG GGA CCT CAT GGA TTA CTT TCC AAA TCT GTC CAA CTC AAT 1550
Arg Pro Leu Gly Pro His Gly Leu Leu Ser Lys Ser Val Gln Leu Asn
                485                 490                 495

GGT CTA ACT CTA AAG ATG GTG GAT GAT CAA ACC TTG CCA CCT TTA ATG 1598
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Gly Leu Thr Leu Lys Met Val Asp Asp Gln Thr Leu Pro Pro Leu Met
500 505 510

GAA AAA CCT CTC CGG CCA GGA AGT TCA CTG GGC TTG CCA GCT TTC TCA 1646
Glu Lys Pro Leu Arg Pro Gly Ser Ser Leu Gly Leu Pro Ala Phe Ser
515 520 525

TAT AGT TTT TTT GTG ATA AGA AAT GCC AAA GTT GCT GCT TGC ATC TGA 1694
Tyr Ser Phe Phe Val Ile Arg Asn Ala Lys Val Ala Ala Cys Ile
530 535 540 543

AAA TAA AAT ATA CTA GTC CTG ACA CTG 1721

(2) INFORMATION FOR SEQ ID NO:12:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 824
(B) TYPE: nucleic acid
(C) STRANDEDNESS: double
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:12

CTGGCAAGAA GGTCTGGTTG GGAGAGACGA GCTCAGCTTA CGGTGGCGGT GCACCCTTGC 60
TGTCCAACAC CTTTGCAGCT GGCTTTATGT GGCTGGATAA ATTGGGCCTG TCAGCCCAGA 120
TGGGCATAGA AGTCGTGATG AGGCAGGTGT TCTTCGGAGC AGGCAACTAC CACTTAGTGG 180
ATGAAAACTT TGAGCCTTTA CCTGATTACT GGCTCTCTCT TCTGTTCAAG AAACTGGTAG 240
GTCCCAGGGT GTTACTGTCA AGAGTGAAAG GCCCAGACAG GAGCAAACTC CGAGTGTATC 300
TCCACTGCAC TAACGTCTAT CACCCACGAT ATCAGGAAGG AGATCTAACT CTGTATGTCC 360
TGAACCTCCA TAATGTCACC AAGCACTTGA AGGTACCGCC TCCGTTGTTC AGGAAACCAG 420
TGGATACGTA CCTTCTGAAG CCTTCGGGGC CGGATGGATT ACTTTCCAAA TCTGTCCAAC 480
TGAACGGTCA AATTCTGAAG ATGGTGGATG AGCAGACCCT GCCAGCTTTG ACAGAAAAAC 540
CTCTCCCCGC AGGAAGTGCA CTAAGCCTGC CTGCCTTTTC CTATGGTTTT TTTGTCATAA 600
GAAATGCCAA AATCGCTGCT TGTATATGAA AATAAAAGGC ATACGGTACC CCTGAGACAA 660
AAGCCGAGGG GGGTGTTATT CATAAAAACAA AACCCTAGTT TAGGAGGCCA CCTCCTTGCC 720
GAGTTCCAGA GCTTCGGGAG GGTGGGGTAC ACTTCAGTAT TACATTCAGT GTGGTGTTCT 780
CTCTAAGAAG AATACTGCAG GTGGTGACAG TTAATAGCAC TGTG 824

(2) INFORMATION FOR SEQ ID NO:13:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 1899
(B) TYPE: nucleic acid
(C) STRANDEDNESS: double
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:13

GGGAAAGCGA GCAAGGAAGT AGGAGAGAGC CGGGCAGGCG GGGCGGGGTT GGATTGGGAG 60
CAGTGGGAGG GATGCAGAAG AGGAGTGGGA GGGATGGAGG GCGCAGTGGG AGGGGTGAGG 120
AGGCGTAACG GGGCGGAGGA AAGGAGAAAA GGGCGCTGGG GCTCGGCGGG AGGAAGTGCT 180
AGAGCTCTCG ACTCTCCGCT GCGCGGCAGC TGGCGGGGGG AGCAGCCAGG TGAGCCCAAG 240
ATGCTGCTGC GCTCGAAGCC TGCGCTGCCG CCGCCGCTGA TGCTGCTGCT CCTGGGGCCG 300
CTGGGTCCCC TCTCCCCTGG CGCCCTGCCC CGACCTGCGC AAGCACAGGA CGTCGTGGAC 360
CTGGACTTCT TCACCCAGGA GCCGCTGCAC CTGGTGAGCC CCTCGTTCCT GTCCGTCACC 420
ATTGACGCCA ACCTGGCCAC GGACCCGCGG TTCCTCATCC TCCTGGGTTC TCCAAAGCTT 480
CGTACCTTGG CCAGAGGCTT GTCTCCTGCG TACCTGAGGT TTGGTGGCAC CAAGACAGAC 540
TTCCTAATTT TCGATCCCAA GAAGGAATCA ACCTTTGAAG AGAGAAGTTA CTGGCAATCT 600
CAAGTCAACC AGGATATTTG CAAATATGGA TCCATCCCTC CTGATGTGGA GGAGAAGTTA 660
CGGTTGGAAT GGCCCTACCA GGAGCAATTG CTACTCCGAG AACACTACCA GAAAAAGTTC 720
AAGAACAGCA CCTACTCAAG AAGCTCTGTA GATGTGCTAT ACACTTTTGC AAACTGCTCA 780

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GGACTGGACT TGATCTTTGG CCTAAATGCG TTATTAAGAA CAGCAGATTT GCAGTGGAAC  840
AGTTCTAATG CTCAGTTGCT CCTGGACTAC TGCTCTTCCA AGGGGTATAA CATTTCTTGG  900
GAACTAGGCA ATGAACCTAA CAGTTTCCTT AAGAAGGCTG ATATTTTCAT CAATGGGTCG  960
CAGTTAGGAG AAGATTATAT TCAATTGCAT AAACTTCTAA GAAAGTCCAC CTTCAAAAAT 1020
GCAAAACTCT ATGGTCCTGA TGTTGGTCAG CCTCGAAGAA AGACGGCTAA GATGCTGAAG 1080
AGCTTCCTGA AGGCTGGTGG AGAAGTGATT GATTCAGTTA CATGGCATCA CTACTATTTG 1140
AATGGACGGA CTGCTACCAG GGAAGATTTT CTAAACCCTG ATGTATTGGA CATTTTTATT 1200
TCATCTGTGC AAAAAGTTTT CCAGGTGGTT GAGAGCACCA GGCCTGGCAA GAAGGTCTGG 1260
TTAGGAGAAA CAAGCTCTGC ATATGGAGGC GGAGCGCCCT TGCTATCCGA CACCTTTGCA 1320
GCTGGCTTTA TGTGGCTGGA TAAATTGGGC CTGTCAGCCC GAATGGGAAT AGAAGTGGTG 1380
ATGAGGCAAG TATTCTTTGG AGCAGGAAAC TACCATTTAG TGGATGAAAA CTTCGATCCT 1440
TTACCTGATT ATTGGCTATC TCTTCTGTTC AAGAAATTGG TGGGCACCAA GGTGTTAATG 1500
GCAAGCGTGC AAGGTTCAAA GAGAAGGAAG CTTCGAGTAT ACCTTCATTG CACAAACACT 1560
GACAATCCAA GGTATAAAGA AGGAGATTTA ACTCTGTATG CCATAAACCT CCATAACGTC 1620
ACCAAGTACT TGCGGTTACC CTATCCTTTT TCTAACAAGC AAGTGGATAA ATACCTTCTA 1680
AGACCTTTGG GACCTCATGG ATTACTTTCC AAATCTGTCC AACTCAATGG TCTAACTCTA 1740
AAGATGGTGG ATGATCAAAC CTTGCCACCT TTAATGGAAA AACCTCTCCG GCCAGGAAGT 1800
TCACTGGGCT TGCCAGCTTT CTCATATAGT TTTTTTGTGA TAAGAAATGC CAAAGTTGCT 1860
GCTTGCATCT GAAAATAAAA TATACTAGTC CTGACACTG                        1899
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(2) INFORMATION FOR SEQ ID NO:14:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 592

(B) TYPE: amino acid

(C) STRANDEDNESS: singl

(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:14

```
Met Glu Gly Ala Val Gly Gly Val Arg Arg Arg Asn Gly Ala Glu
                5                   10                  15
Glu Arg Arg Lys Gly Arg Trp Gly Ser Ala Gly Gly Ser Ala Arg
                20                  25                  30
Ala Leu Asp Ser Pro Leu Arg Gly Ser Trp Arg Gly Glu Gln Pro
                35                  40                  45
Gly Glu Pro Lys Met Leu Leu Arg Ser Lys Pro Ala Leu Pro Pro
                50                  55                  60
Pro Leu Met Leu Leu Leu Leu Gly Pro Leu Gly Pro Leu Ser Pro
                65                  70                  75
Gly Ala Leu Pro Arg Pro Ala Gln Ala Gln Asp Val Val Asp Leu
                80                  85                  90
Asp Phe Phe Thr Gln Glu Pro Leu His Leu Val Ser Pro Ser Phe
                95                  100                 105
Leu Ser Val Thr Ile Asp Ala Asn Leu Ala Thr Asp Pro Arg Phe
                110                 115                 120
Leu Ile Leu Leu Gly Ser Pro Lys Leu Arg Thr Leu Ala Arg Gly
                125                 130                 135
Leu Ser Pro Ala Tyr Leu Arg Phe Gly Gly Thr Lys Thr Asp Phe
                140                 145                 150
Leu Ile Phe Asp Pro Lys Lys Glu Ser Thr Phe Glu Glu Arg Ser
                155                 160                 165
Tyr Trp Gln Ser Gln Val Asn Gln Asp Ile Cys Lys Tyr Gly Ser
                170                 175                 180
Ile Pro Pro Asp Val Glu Glu Lys Leu Arg Leu Glu Trp Pro Tyr
                185                 190                 195
Gln Glu Gln Leu Leu Leu Arg Glu His Tyr Gln Lys Lys Phe Lys
                200                 205                 210
Asn Ser Thr Tyr Ser Arg Ser Ser Val Asp Val Leu Tyr Thr Phe
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                215                     220                     225
Ala Asn Cys Ser Gly Leu Asp Leu Ile Phe Gly Leu Asn Ala Leu
                230                     235                     240
Leu Arg Thr Ala Asp Leu Gln Trp Asn Ser Ser Asn Ala Gln Leu
                245                     250                     255
Leu Leu Asp Tyr Cys Ser Ser Lys Gly Tyr Asn Ile Ser Trp Glu
                260                     265                     270
Leu Gly Asn Glu Pro Asn Ser Phe Leu Lys Lys Ala Asp Ile Phe
                275                     280                     285
Ile Asn Gly Ser Gln Leu Gly Glu Asp Tyr Ile Gln Leu His Lys
                290                     295                     300
Leu Leu Arg Lys Ser Thr Phe Lys Asn Ala Lys Leu Tyr Gly Pro
                305                     310                     315
Asp Val Gly Gln Pro Arg Arg Lys Thr Ala Lys Met Leu Lys Ser
                320                     325                     330
Phe Leu Lys Ala Gly Gly Glu Val Ile Asp Ser Val Thr Trp His
                335                     340                     345
His Tyr Tyr Leu Asn Gly Arg Thr Ala Thr Arg Glu Asp Phe Leu
                350                     355                     360
Asn Pro Asp Val Leu Asp Ile Phe Ile Ser Ser Val Gln Lys Val
                365                     370                     375
Phe Gln Val Val Glu Ser Thr Arg Pro Gly Lys Lys Val Trp Leu
                380                     385                     390
Gly Glu Thr Ser Ser Ala Tyr Gly Gly Gly Ala Pro Leu Leu Ser
                395                     400                     405
Asp Thr Phe Ala Ala Gly Phe Met Trp Leu Asp Lys Leu Gly Leu
                410                     415                     420
Ser Ala Arg Met Gly Ile Glu Val Val Met Arg Gln Val Phe Phe
                425                     430                     435
Gly Ala Gly Asn Tyr His Leu Val Asp Glu Asn Phe Asp Pro Leu
                440                     445                     450
Pro Asp Tyr Trp Leu Ser Leu Leu Phe Lys Lys Leu Val Gly Thr
                455                     460                     465
Lys Val Leu Met Ala Ser Val Gln Gly Ser Lys Arg Arg Lys Leu
                470                     475                     480
Arg Val Tyr Leu His Cys Thr Asn Thr Asp Asn Pro Arg Tyr Lys
                485                     490                     495
Glu Gly Asp Leu Thr Leu Tyr Ala Ile Asn Leu His Asn Val Thr
                500                     505                     510
Lys Tyr Leu Arg Leu Pro Tyr Pro Phe Ser Asn Lys Gln Val Asp
                515                     520                     525
Lys Tyr Leu Leu Arg Pro Leu Gly Pro His Gly Leu Leu Ser Lys
                530                     535                     540
Ser Val Gln Leu Asn Gly Leu Thr Leu Lys Met Val Asp Asp Gln
                545                     550                     555
Thr Leu Pro Pro Leu Met Glu Lys Pro Leu Arg Pro Gly Ser Ser
                560                     565                     570
Leu Gly Leu Pro Ala Phe Ser Tyr Ser Phe Phe Val Ile Arg Asn
                575                     580                     585
Ala Lys Val Ala Ala Cys Ile
                590     592
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(2) INFORMATION FOR SEQ ID NO:15:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 1899

(B) TYPE: nucleic acid

(C) STRANDEDNESS: double

(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:15

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                                                         GGG     3
AAA GCG AGC AAG GAA GTA GGA GAG AGC CGG GCA GGC GGG GCG GGG    48
TTG GAT TGG GAG CAG TGG GAG GGA TGC AGA AGA GGA GTG GGA GGG    93
ATG GAG GGC GCA GTG GGA GGG GTG AGG AGG CGT AAC GGG GCG GAG   138
Met Glu Gly Ala Val Gly Gly Val Arg Arg Arg Asn Gly Ala Glu
                  5                  10                  15

GAA AGG AGA AAA GGG CGC TGG GGC TCG GCG GGA GGA AGT GCT AGA   183
Glu Arg Arg Lys Gly Arg Trp Gly Ser Ala Gly Gly Ser Ala Arg
                 20                  25                  30

GCT CTC GAC TCT CCG CTG CGC GGC AGC TGG CGG GGG GAG CAG CCA   228
Ala Leu Asp Ser Pro Leu Arg Gly Ser Trp Arg Gly Glu Gln Pro
                 35                  40                  45

GGT GAG CCC AAG ATG CTG CTG CGC TCG AAG CCT GCG CTG CCG CCG   273
Gly Glu Pro Lys Met Leu Leu Arg Ser Lys Pro Ala Leu Pro Pro
                 50                  55                  60

CCG CTG ATG CTG CTG CTC CTG GGG CCG CTG GGT CCC CTc TCC CCT   318
Pro Leu Met Leu Leu Leu Leu Gly Pro Leu Gly Pro Leu Ser Pro
                 65                  70                  75

GGC GCC CTG CCC CGA CCT GCG CAA GCA CAG GAC GTc GTG GAC CTG   363
Gly Ala Leu Pro Arg Pro Ala Gln Ala Gln Asp Val Val Asp Leu
                 80                  85                  90

GAC TTc TTC ACC CAG GAG CCG CTG CAC CTG GTG AGC CCC TCG TTC   408
Asp Phe Phe Thr Gln Glu Pro Leu His Leu Val Ser Pro Ser Phe
                 95                 100                 105

CTG TCC GTC ACC ATT GAC GCC AAC CTG GCC ACG GAC CCG CGG TTC   453
Leu Ser Val Thr Ile Asp Ala Asn Leu Ala Thr Asp Pro Arg Phe
                110                 115                 120

CTC ATC CTC CTG GGT TCT CCA AAG CTT CGT ACC TTG GCC AGA GGC   498
Leu Ile Leu Leu Gly Ser Pro Lys Leu Arg Thr Leu Ala Arg Gly
                125                 130                 135

TTG TCT CCT GCG TAC CTG AGG TTT GGT GGC ACC AAG ACA GAC TTC   543
Leu Ser Pro Ala Tyr Leu Arg Phe Gly Gly Thr Lys Thr Asp Phe
                140                 145                 150

CTA ATT TTC GAT CCC AAG AAG GAA TCA ACC TTT GAA GAG AGA AGT   588
Leu Ile Phe Asp Pro Lys Lys Glu Ser Thr Phe Glu Glu Arg Ser
                155                 160                 165

TAC TGG CAA TCT CAA GTC AAC CAG GAT ATT TGC AAA TAT GGA TCC   633
Tyr Trp Gln Ser Gln Val Asn Gln Asp Ile Cys Lys Tyr Gly Ser
                170                 175                 180

ATC CCT CCT GAT GTG GAG GAG AAG TTA CGG TTG GAA TGG CCC TAC   678
Ile Pro Pro Asp Val Glu Glu Lys Leu Arg Leu Glu Trp Pro Tyr
                185                 190                 195
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CAG GAG CAA TTG CTA CTC CGA GAA CAC TAC CAG AAA AAG TTC AAG    723
Gln Glu Gln Leu Leu Leu Arg Glu His Tyr Gln Lys Lys Phe Lys
                200                 205                 210

AAC AGC ACC TAC TCA AGA AGC TCT GTA GAT GTG CTA TAC ACT TTT    768
Asn Ser Thr Tyr Ser Arg Ser Ser Val Asp Val Leu Tyr Thr Phe
                215                 220                 225

GCA AAC TGC TCA GGA CTG GAC TTG ATC TTT GGC CTA AAT GCG TTA    813
Ala Asn Cys Ser Gly Leu Asp Leu Ile Phe Gly Leu Asn Ala Leu
                230                 235                 240

TTA AGA ACA GCA GAT TTG CAG TGG AAC AGT TCT AAT GCT CAG TTG    858
Leu Arg Thr Ala Asp Leu Gln Trp Asn Ser Ser Asn Ala Gln Leu
                245                 250                 255

CTC CTG GAC TAC TGC TCT TCC AAG GGG TAT AAC ATT TCT TGG GAA    903
Leu Leu Asp Tyr Cys Ser Ser Lys Gly Tyr Asn Ile Ser Trp Glu
                260                 265                 270

CTA GGC AAT GAA CCT AAC AGT TTC CTT AAG AAG GCT GAT ATT TTC    948
Leu Gly Asn Glu Pro Asn Ser Phe Leu Lys Lys Ala Asp Ile Phe
                275                 280                 285

ATC AAT GGG TCG CAG TTA GGA GAA GAT TAT ATT CAA TTG CAT AAA    993
Ile Asn Gly Ser Gln Leu Gly Glu Asp Tyr Ile Gln Leu His Lys
                290                 295                 300

CTT CTA AGA AAG TCC ACC TTC AAA AAT GCA AAA CTC TAT GGT CCT    1038
Leu Leu Arg Lys Ser Thr Phe Lys Asn Ala Lys Leu Tyr Gly Pro
                305                 310                 315

GAT GTT GGT CAG CCT CGA AGA AAG ACG GCT AAG ATG CTG AAG AGC    1083
Asp Val Gly Gln Pro Arg Arg Lys Thr Ala Lys Met Leu Lys Ser
                320                 325                 330

TTC CTG AAG GCT GGT GGA GAA GTG ATT GAT TCA GTT ACA TGG CAT    1128
Phe Leu Lys Ala Gly Gly Glu Val Ile Asp Ser Val Thr Trp His
                335                 340                 345

CAC TAC TAT TTG AAT GGA CGG ACT GCT ACC AGG GAA GAT TTT CTA    1173
His Tyr Tyr Leu Asn Gly Arg Thr Ala Thr Arg Glu Asp Phe Leu
                350                 355                 360

AAC CCT GAT GTA TTG GAC ATT TTT ATT TCA TCT GTG CAA AAA GTT    1218
Asn Pro Asp Val Leu Asp Ile Phe Ile Ser Ser Val Gln Lys Val
                365                 370                 375

TTC CAG GTG GTT GAG AGC ACC AGG CCT GGC AAG AAG GTC TGG TTA    1263
Phe Gln Val Val Glu Ser Thr Arg Pro Gly Lys Lys Val Trp Leu
                380                 385                 390

GGA GAA ACA AGC TCT GCA TAT GGA GGC GGA GCG CCC TTG CTA TCC    1308
Gly Glu Thr Ser Ser Ala Tyr Gly Gly Gly Ala Pro Leu Leu Ser
                395                 400                 405
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GAC ACC TTT GCA GCT GGC TTT ATG TGG CTG GAT AAA TTG GGC CTG    1353
Asp Thr Phe Ala Ala Gly Phe Met Trp Leu Asp Lys Leu Gly Leu
                410                 415                 420

TCA GCC CGA ATG GGA ATA gAA GTG GTG ATG AGG CAA GTA TTC TTT    1398
Ser Ala Arg Met Gly Ile Glu Val Val Met Arg Gln Val Phe Phe
                425                 430                 435

GGA GCA GGA AAC TAC CAT TTA GTG GAT GAA AAC TTC GAT CCT TTA    1443
Gly Ala Gly Asn Tyr His Leu Val Asp Glu Asn Phe Asp Pro Leu
                440                 445                 450

CCT GAT TAT TGG CTA TCT CTT CTG TTC AAG AAA TTG GTG GGC ACC    1488
Pro Asp Tyr Trp Leu Ser Leu Leu Phe Lys Lys Leu Val Gly Thr
                455                 460                 465

AAG GTG TTA ATG GCA AGC GTG CAA GGT TCA AAG AGA AGG AAG CTT    1533
Lys Val Leu Met Ala Ser Val Gln Gly Ser Lys Arg Arg Lys Leu
                470                 475                 480

CGA GTA TAC CTT CAT TGC ACA AAC ACT GAC AAT CCA AGG TAT AAA    1578
Arg Val Tyr Leu His Cys Thr Asn Thr Asp Asn Pro Arg Tyr Lys
                485                 490                 495

GAA GGA GAT TTA ACT CTG TAT GCC ATA AAC CTC CAT AAC GTC ACC    1623
Glu Gly Asp Leu Thr Leu Tyr Ala Ile Asn Leu His Asn Val Thr
                500                 505                 510

AAG TAC TTG CGG TTA CCC TAT CCT TTT TCT AAC AAG CAA GTG GAT    1668
Lys Tyr Leu Arg Leu Pro Tyr Pro Phe Ser Asn Lys Gln Val Asp
                515                 520                 525

AAA TAC CTT CTA AGA CCT TTG GGA CCT CAT GGA TTA CTT TCC AAA    1713
Lys Tyr Leu Leu Arg Pro Leu Gly Pro His Gly Leu Leu Ser Lys
                530                 535                 540

TCT GTC CAA CTC AAT GGT CTA ACT CTA AAG ATG GTG GAT GAT CAA    1758
Ser Val Gln Leu Asn Gly Leu Thr Leu Lys Met Val Asp Asp Gln
                545                 550                 555

ACC TTG CCA CCT TTA ATG GAA AAA CCT CTC CGG CCA GGA AGT TCA    1803
Thr Leu Pro Pro Leu Met Glu Lys Pro Leu Arg Pro Gly Ser Ser
                560                 565                 570

CTG GGC TTG CCA GCT TTC TCA TAT AGT TTT TTT GTG ATA AGA AAT    1848
Leu Gly Leu Pro Ala Phe Ser Tyr Ser Phe Phe Val Ile Arg Asn
                575                 580                 585

GCC AAA GTT GCT GCT TGC ATC TGA AAA TAA AAT ATA CTA GTC CTG    1893
Ala Lys Val Ala Ala Cys Ile
                590     592

ACA CTG                                                        1899
```

(2) INFORMATION FOR SEQ ID NO:16:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 594

(B) TYPE: nucleic acid

(C) STRANDEDNESS: double
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:16

ATTACTATAG GGCACGCGTG GTCGACGGCC CGGGCTGGTA TTGTCTTAAT GAGAAGTTGA 60
TAAAGAATTT TGGGTGGTTG ATCTCTTTCC AGCTGCAGTT TAGCGTATGC TGAGGCCAGA 120
TTTTTTCAGG CAAAAGTAAA ATACCTGAGA AACTGCCTGG CCAGAGGACA ATCAGATTTT 180
GGCTGGCTCA AGTGACAAGC AAGTGTTTAT AAGCTAGATG GGAGAGGAAG GGATGAATAC 240
TCCATTGGAG GCTTTACTCG AGGGTCAGAG GGATACCCGG CGCCATCAGA ATGGGATCTG 300
GGAGTCGGAA ACGCTGGGTT CCCACGAGAG CGCGCAGAAC ACGTGCGTCA GGAAGCCTGG 360
TCCGGGATGC CCAGCGCTGC TCCCCGGGCG CTCCTCCCCG GGCGCTCCTC CCCAGGCCTC 420
CCGGGCGCTT GGATCCCGGC CATCTCCGCA CCCTTCAAGT GGGTGTGGGT GATTTCGTAA 480
GTGAACGTGA CCGCCACCGG GGGGAAAGCG AGCAAGGAAG TAGGAGAGAG CCGGGCAGGC 540
GGGGCGGGGT TGGATTGGGA GCAGTGGGAG GGATGCAGAA GAGGAGTGGG AGGG 594

(2) INFORMATION FOR SEQ ID NO:17:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 21
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:17
CCCCAGGAGC AGCAGCATCA G 21

(2) INFORMATION FOR SEQ ID NO:18:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 21
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:18
AGGCTTCGAG CGCAGCAGCA T 21

(2) INFORMATION FOR SEQ ID NO:19:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 22
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:19
GTAATACGAC TCACTATAGG GC 22

(2) INFORMATION FOR SEQ ID NO:20:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 19
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:20
ACTATAGGGC ACGCGTGGT 19

(2) INFORMATION FOR SEQ ID NO:21:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 21
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:21
CTTGGGCTCA CCTGGCTGCT C 21

(2) INFORMATION FOR SEQ ID NO:22:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 23
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:22
AGCTCTGTAG ATGTGCTATA CAC 23

(2) INFORMATION FOR SEQ ID NO:23:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 22
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:23
GCATCTTAGC CGTCTTTCTT CG 22

(2) INFORMATION FOR SEQ ID NO:24:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 23
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:24
GAGCAGCCAG GTGAGCCCAA GAT 23

(2) INFORMATION FOR SEQ ID NO:25:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 23
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:25
TTCGATCCCA AGAAGGAATC AAC 23

(2) INFORMATION FOR SEQ ID NO:26:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 23
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:26
AGCTCTGTAG ATGTGCTATA CAC 23

(2) INFORMATION FOR SEQ ID NO:27:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 24
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:27
TCAGATGCAA GCAGCAACTT TGGC 24

(2) INFORMATION FOR SEQ ID NO:28:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 22
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:28
GCATCTTAGC CGTCTTTCTT CG 22

(2) INFORMATION FOR SEQ ID NO:29:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 24
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:29
GTAGTGATGC CATGTAACTG AATC 24

(2) INFORMATION FOR SEQ ID NO:30:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 22
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:30
AGGCACCCTA GAGATGTTCC AG 22

(2) INFORMATION FOR SEQ ID NO:31:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 24
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:31
GAAGATTTCT GTTTCCATGA CGTG 24

(2) INFORMATION FOR SEQ ID NO:32:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 25
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:32
CCACACTGAA TGTAATACTG AAGTG 25

(2) INFORMATION FOR SEQ ID NO:33:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 22
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:33
CGAAGCTCTG GAACTCGGCA AG 22

(2) INFORMATION FOR SEQ ID NO:34:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 22

(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:34

GCCAGCTGCA AAGGTGTTGG AC 22

(2) INFORMATION FOR SEQ ID NO:35:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 23
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:35

AACACCTGCC TCATCACGAC TTC 23

(2) INFORMATION FOR SEQ ID NO:36:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 22
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:36

GCCAGGCTGG CGTCGATGGT GA 22

(2) INFORMATION FOR SEQ ID NO:37:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 22
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:37

GTCGATGGTG ATGGACAGGA AC 22

(2) INFORMATION FOR SEQ ID NO:38:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 22
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:38

GTAATACGAC TCACTATAGG GC 22

(2) INFORMATION FOR SEQ ID NO:39:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 19
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:39

ACTATAGGGC ACGCGTGGT 19

(2) INFORMATION FOR SEQ ID NO:40:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 27
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:40

CCATCCTAAT ACGACTCACT ATAGGGC 27

(2) INFORMATION FOR SEQ ID NO:41:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 23

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:41

ACTCACTATA GGGCTCGAGC GGC 23

(2) INFORMATION FOR SEQ ID NO:42:

(i) SEQUENCB CHARACTERISTICS:

(A) LENGTH: 44848

(B) TYPE: nucleic acid

(C) STRANDEDNESS: double

(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:42

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TTTAGAAAAC TTGCAATGGT CCACTTTTCA AATCACCCAA ACATGTTAAA    300
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CGATGTCTCA TTATGTTGCC CAGGCTGGTC TCAAACTCCT AAGCTCAAGT 38600
GATCTTCCTC AGCCTCCCAA AGTGCTGGGA TTACAGGCAT GAAAAACTGC 38650
ACCCAGCCCT AAAAATTATT AGGGTCCTGC ATAGTAAGAC TTTAATAAAT 38700
ATTTAAATGA ACATCTGGTT TTTTTAAAAA AAAAATAGAG ACAAGGTCTC 38750
ACTATATTGC CCAAGCTGGT CTCGAACTCC TGGACTCACG CAATCCTGCT 38800
GCCTTAGCCG CCCAAAGTGC TGGGATTACA GGCATGACCC ACCTCATCTG 38850
GGCTGAGTGA ACATATTTTT AACATAAAGG CCGTATTTTA TATTTATCTC 38900
ATACATTTTG CCCAGCATCC CCATTTCCGC CGAATCTGTT GCTTGCTAAT 38950
TCCTTCCAGC TTCATTTCAT CTGAAATTTG ACAAACATCT TCTATTTCTT 39000
TGTCGTCATG TTATTGACTT CAGAATATAA AATAAAACAC TATACCCAAA 39050
TTAAACCCCA CCCTCATTGC CCAGCCTGAT GTGAAAATAA TCAGCATACA 39100
TTAAGCTTAC CCTTGATATA TGTGTAGCAT CTTTTAGATA AATATACAGC 39150
TGATTAAGCA ATATAGCCTG ATGGTATAAT ATCTTGCCCA TGTACCTCAT 39200
CTTATCTCCA GCAGGATTAA TTCACAGTGA TCAGATTTAC CTTTAAACTT 39250
TGTAGCAAAA TATCCTCTCC AAAAGCATAT CTAAAACTTT TGTGTGTACT 39300
CTTGCAAGTT TCTTAATTTC ATGCAGAACA GGCTCTTACC ACTGTTAGCT 39350
GGAGATATTT TCAAGACCTA TTTTTGTTTG TGGTTTCCTG ATGATGGTCA 39400
TGGCATTTCC CCCTTCACTC CATCTAAAAA TTGAGGTGAT ACAGGCTTTT 39450
AAACAAAACC AACTCATATA GACTGAGTAC AACTGCAATG CAGGCATGCT- 39500
AACCTCTGCT ACAATCATGG GCGTGCTATT GATATGTCTT AAGTTACAGA 39550
ACACAGGGCT GAGCGTCTCA TTAGGTCAAA ATGTAAACCA GTTTTTCTGC 39600
TCACTGATGC TTAATGAGGA CAGGGTGTGA GAGATTTCTT TAAGGAAAAC 39650
AAATATATAA TAATGCTACA TGGAAAAATA TCTAACATTA GAGAATTAAG 39700
TAAATAAACT AATATACTCA CACCATGGAA TCTTGTGCAG ACATTAAAAT 39750
TATGTAGTGG ATGGATGTTT AATGGTGTGA GAAAAAGTTA GGATGTGCTG 39800
GGGTGGGGGG AAGAATCAAG TTTTAAGAAA ATACAGTATA CCCATACTTA 39850
AGTAAAAAAA AAAAAAAAGG TATGTACAGT CATGTGTTGC TTAATGATGG 39900

GGATACATTC CGAGAAATGT GTCGATAGGT GATTTCATCC TTGTGTGAAC 39950
ATCATAGAGT GAACTTACAC AAACCTAGAT GGTCTAGCCT ACTATGTATC 40000
TAGGCTATAT GACTAGCCTG TTGCTCCTAG GCTACAAACC TGTAAAGCAT 40050
GTTACTGTAG CGAATATACA AATACTTAAC ACAATGGCAA GCTATCATTG 40100
TGTTAAGTAG TTGTGTATCT AAACATATCT AAAACATAGA AAACTAATGT 40150
GTTGTGCTAC AATGTTACAA TGACTATGAC ATTGCTAGGC AATAGGAATT 40200
ATAATTTTAT CCTTTTATGG AACCACACTT ATATATGCGG TCCATGGTGG 40250
ACCAAAACAT CCTTATGTGG CATATGACTG TATACATGTA CACAAAAAAT 40300
AGATGAAAGA ATGAATATAC ATCAAAATAT TTAAAATGGT TATAATGACT 40350
TAGGTTACTT TTATTTATCT TAGTAATAAT AATGATGATA GATAATACTT 40400
TTATAGTGTT TACTATATAA AAGACACTGT TATAAGTGTT CTACATACTT 40450
TACATGTATT ACCTAAATGA TATAAATATA ACTCTGACAG TAACTAATCT 40500
TATACGTTCT CTTTTCTTTT TTTTTTTTTT CTTTTTTTAG ACAGAATCTT 40550
GCTCTACCAG GCTGGAGTGC AGGGTGCAAT CTCGGCTCAC TGCAACCTCC 40600
GCCTCCCAGG TTCAAACGAT TCTCATGTCT CAGCCTCCTG AGTAGCTGGG 40650
ACTACAGGCA CACACCACCA TGCCCGGCTA ATTTTTGTAT TTTTGGGTAG 40700
AGATGGAGTT TTGCCATGTT GGCCAGGCTG ATCTTGAACT CCTGGCCTCA 40750
AGTGATCTGC CTGCCTCAGC CTCCCAAAGT GCTGGGATTA CAGGTGTGAA 40800
CCACTGTGCT CGGCCTAATC TTACAAGTTT TCAATATTTA AAGAGTGCTA 40850
ACTTTGTTGA CAATATAAAA CATATTTGAG AAAAAGAGAT ATAAGCATCT 40900
TATTTAGAAT TATGAAAATA TCAATAGACC TACAGCCGAC TAAAGCTTTT 40950
CTTCATAAGC TCTTGCCTAT ATTGATTCGC TCCTGTGAAT ATGCATTAAT 41000
TTGATTTAAA TAATAAGTAT GTATAAGAAA TAACACTTTT CCTTAATTTT 41050
TAAGAACGTT CAACAGTTTT TAATTTGAAT TCCAATAGTG AAATACATAG 41100
AAAATATAAA ATTTTCTGTA GTTTAGCCAA ATTGTTTTTG TTTCACCACA 41150
GCATTCTACC AAAATTTCTT AATAACAGTA AGAAAATGAA TGCATACCTC 41200
CTGCAGGGAG AGGGGAGTTA GGCAGTTTAT GGGCATAGTT ACAAGTGAGA 41250
AATTTCATTG GCTACCATTT ACGCTAAATT CATAAAAACT GCATTCAATT 41300
CTATATATCT ATTTTCTTTA CATAAAAAAG GTTTCAATTA TTGGCCATTA 41350
AATAAAATAG CCACCATTCC AGAAGTTGTG TCATGTTTAT CCTTTTTATA 41400
CCACCATCAT ATTGCCTATT ATATAGATTG TGTGTGTTCC ATTTTCTGTA 41450
ATGGGCCAGA CAGTAAGTAT TTCTGGCTTT GGAGTCCATA TGGTCTCTAT 41500
CATAACTACT CATCTCTGCC ATTGTAGCTT AAAGATTATC TAGGTCAAAT 41550
GCCTAAGTGA TATAGTGTTG AAATACAAGT TATATAATAT AGGCTGCCAC 41600
AAAAAAAAAT TTATTTGGTC TAAAAAAGAT TTCATGACTT TTGTAGCAGC 41650
ATGGGTGGGG CATGCACCAC TTGGTTAACT CGGTGTATCT TTCTCCTTTG 41700
CAGATCTGTC CAACTCAATG GTCTAACTCT AAAGATGGTG GATGATCAAA 41750
CCTTGCCACC TTTAATGGAA AAACCTCTCC GGCCAGGAAG TTCACTGGGC 41800
TTGCCAGCTT TCTCATATAG TTTTTTTGTG ATAAGAAATG CCAAAGTTGC 41850
TGCTTGCATC TGAAAATAAA ATATACTAGT CCTGACACTG AATTTTTCAA 41900
GTATACTAAG AGTAAAGCAA CTCAAGTTAT AGGAAAGGAA GCAGATACCT 41950
TGCAAAGCAA CTAGTGGGTG CTTGAGAGAC ACTGGGACAC TGTCAGTGCT 42000
AGATTTAGCA CAGTATTTTG ATCTCGCTAG GTAGAACACT GCTAATAATA 42050
ATAGCTAATA ATACCTTGTT CCAAATACTG CTTAGCATTT TGCATGTTTT 42100
ACTTTTATCT AAAGTTTTGT TTTGTTTTAT TATTTATTTA TTTATTTATT 42150
TTGAGACAGA ATCTCTCTCT GTCACCCAGG CTGGAGTGCC ATGGTGCGAT 42200
CTTGGCTCAC TGCAACTTTA AGCAATTCTC CTGCCTCAGC TTCCTGAGTA 42250
GCTGGGATTA TAGGCGTGTG CCACCACGCC CAGCTACTTT CTATATTTTT 42300
TGTAGAGATG GAGTTTCGCC ATATTGGCCA AGCTGGTCTC GAACTCCTGT 42350
CCTCGAACTC CTGTCCTCAA GTGATCCACC CGCCTCAGCC TCTCAAAGTG 42400
CTGGGATTAC AGGTGTGAGC CACCACACCC AGCAGTGTTT TATTTTTGAG 42450
ACAGGGTATC ATTCTGTTGC CCAGGCTTGA GTGCAGTGGT GCAATCATAG 42500
ATCACTGCAG CCTTTTAACT CCTGGGCTCA AGTCATCCTC CTGCTTAGCC 42550
TCCCAAGTAG CTAGGACCAC AGACACATGC CATCACACTT GGCTATTTTT 42600
AAAAAATTTT TTGTAGAGAT GGGGTCTCGC TATGTTACCC AAACTGGTCC 42650
TGAACTCCTG GACTCAATTG ATCCTCCCAC CTTGGCCTTC CAGGTGCTGG 42700
GATTTCTTTG GGAGTACAGC ATGGTACAGC AGGAGATCAT TTGATGTTAC 42750
CTCTGTGCAG TGTTGCTAGT CAGCGAAAGA CTATAATACC TGTGGGGACA 42800
GCGATTAGCC ACCACAACCA GTCTTTATTT AAAGTTATTA AAAATGGCTG 42850
GGCGCAGTGG CTCACACCTG TAATCCTAGC ACTTTGGGAG GCCGAGGCAG 42900
ATGGATCACC TGACGTGAGG AATTTGAGAC CAGCCTGGCC AACATGGTGA 42950
AACCCCATCT CTACTAAAAA ATACAAAAAT TAGCTGGGTG TGGTCCTGTA 43000
GTCCCAGCTA CTTGGGAGGC TGGGGCAGGA GAATTACTTG AACCCAGGAG 43050
GCAGAGGTTG CAGTGAGCCG AGATTGTGCC ACTGCACTCC AGCCTGGGTG 43100
ACAGAGAGAG ATTCCATCTC AAAAAAACAA GTTATTAAAA ATGTATATGA 43150
ATGCTCCTAA TATGGTCAGG AAGCAAGGAA GCGAAGGATA TATTATGAGT 43200
TTTAAGAAGG TGCTTAGCTG TATATTTATC TTTCAAAATG TATTAGAAGA 43250
TTTTAGAATT CTTTCCTTCA TGTGCCATCT CTACAGGCAC CCATCAGAAA 43300
AAGCATACTG CCGTTACCGT GAAACTGGTT GTAAAAGAGA AACTATCTAT 43350
TTGCACCTTA AAAGACAGCT AGATTTTGCT GATTTTCTTC TTTCGGTTTT 43400
CTTTGTCAGC AATAATATGT GAGAGGACAG ATTGTTAGAT ATGATAGTAT 43450
AAAAAATGGT TAATGACAAT TCAGAGGCGA GGAGATTCTG TAAACTTAAA 43500
ATTACTATAA ATGAAATTGA TTTGTCAAGA GGATAAATTT TAGAAAACAC 43550
CCAATACCTT ATAACTGTCT GTTAATGCTT GCTTTTTCTC TACCTTTCTT 43600
CCTTGTTTCA GTTGGGAAGC TTTTGGCTGC AAGTAACAGA AACTCCTAAT 43650

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TCAAATGGCT TAAGCAATAA GGAAATGTAT ATTCCCACAT AACTAGACGT  43700
TCAAACAGGC CAGGCTCCAG CACTTCAGTA CGTCACCAGG GATCTGGGTT  43750
CTTCCCAGCT CTCTGCTCTG CCATCTTTAG CGCTGGCTTC ATTCTCAGAC  43800
TCTGGTAGCA TGATGGCTGT AGCTGTTTCA TGGGCCCCTT CAAACCTCAT  43850
AGCAACCAGA GGAAGAAAAT GAGCCATTTT TTGAGTCTCC TTCATAGACT  43900
TGAATAACTC TTTTTCAGAG CTTCTCACAG CAAACCTCTC CTCATGTCTC  43950
CTCATGTCTT ATTGTTCAGA AATGGGTAAT GTGGCCATTT CACCAGTCAC  44000
TGCCAACAAC AACGAGGTTC CTATAATTGT CTCTGAGTAA CCCTTTGGAA  44050
TGGAGAGGGT GTTGGTCAGT CTACAAACTG AACACTGCAG TTCTGCGCTT  44100
TTTACCAGTG AAAAAATGTA ATTATTTTCC CCTCTTAAGG ATTAATATTC  44150
TTCAAATGTA TGCCTGTTAT GGATATAGTA TCTTTAAAAT TTTTTATTTT  44200
AATAGCTTTA GGGGTACACA CTTTTTGCTT ACAGGGGTGA ATTGTGTAGT  44250
GGTGAAGACT CGGCTTTTAA TGTACTTGTC ACCTGAGTGA TGTACATTGT  44300
ACCCAATAGG TAATTTTTCA TCCATTACCC TCCTTCCGCC CTCTTCCCTT  44350
CTGAGTCTCC AACATCCCTT ATACCACTGT GTATGTTCTT GTGTACCTAC  44400
AGCTAAGCTT CCACTTATAA GTGAGAACAT GCAGTATTTG GTTTTCCATT  44450
CCTGAGTTAC TTCCCTTAGG ATAACAGCCC CCAGTTCCGT CCAAGTTGCT  44500
GCAAAATACA TTATTCTTCT TTATGGCTGA GTAATAGTCC ATGGTACATA  44550
TATACCACAT TTTCTTTATC CACTTATCAG TTGATGGACA CTTAGGTTAA  44600
TTCCATTCAA TTTCATTCAA TTTAAGTATA TTTGTAAGGA GCTAAAGCTG  44650
AAAATTAAAT TTTAGATCTT TCAATACTCT TAAATTTTAT ATGTAAGTGG  44700
TTTTTATATT TTCACATTTG AAATAAAGTA ATTTTTATAA CCTTGATATT  44750
GTATGACTAT TCTTTTAGTA ATGTAAAGCC TACAGACTCC TACATTTGGA  44800
ACCACTAGTG TGTTGTTTCA CCCCTTGTTA TACTATCAGG ATCCTCGA    44848
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(2) INFORMATION FOR SEQ ID NO:43:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 2396

(B) TYPE: nucleic acid

(C) STRANDEDNESS: double

(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:43

```
TTTCTAGTTG CTTTTAGCCA ATGTCGGATC AGGTTTTTCA AGCGACAAAG    50
AGATACTGAG ATCCTGGGCA GAGGACATCC TAGCTCGGTC AGATTTGGGC   100
AGGCTCAAGT GACCAGTGTC TTAAGGCAGA AGGGAGTCGG GGTAGGGTCT   150
GGCTGAACCC TCAACCGGGG CTTTTAACTC AGGGTCTAGT CCTGGCGCCA   200
AATGGATGGG ACCTAGAAAA GGTGACAGAG TGCGCAGGAC ACCAGGAAGC   250
TGGTCCCACC CCTGCGCGGC TCCCGGGCGC TCCCTCCCCA GGCCTCCGAG   300
GATCTTGGAT TCTGGCCACC TCCGCACCCT TTGGATGGGT GTGGATGATT   350
TCAAAAGTGG ACGTGACCGC GGCGGAGGGG AAAGCCAGCA CGGAAATGAA   400
AGAGAGCGAG GAGGGGAGGG CGGGGAGGGG AGGGCGCTAG GGAGGGACTC   450
CCGGGAGGGG TGGGAGGGAT GGAGCGCTGT GGGAGGGTAC TGAGTCCTGG   500
CGCCAGAGGC GAAGCAGGAC CGGTTGCAGG GGGCTTGAGC CAGCGCGCCG   550
GCTGCCCCAG CTCTCCCGGC AGCGGGCGGT CCAGCCAGGT GGGATGCTGA   600
GGCTGCTGCT GCTGTGGCTC TGGGGGCCGC TCGGTGCCCT GGCCCAGGGC   650
GCCCCCGCGG GGACCGCGCC GACCGACGAC GTGGTAGACT TGGAGTTTTA   700
CACCAAGCGG CCGCTCCGAA GCGTGAGTCC CTCGTTCCTG TCCATCACCA   750
TCGACGCCAG CCTGGCCACC GACCCGCGCT TCCTCACCTT CCTGGGCTCT   800
CCAAGGCTCC GTGCTCTGGC TAGAGGCTTA TCTCCTGCAT ACTTGAGATT   850
TGGCGGCACA AAGACTGACT TCCTTATTTT TGATCCGGAC AAGGAACCGA   900
CTTCCGAAGA AAGAAGTTAC TGGAAATCTC AAGTCAACCA TGATATTTGC   950
AGGTCTGAGC CGGTCTCTGC TGCGGTGTTG AGGAAACTCC AGGTGGAATG  1000
GCCCTTCCAG GAGCTGTTGC TGCTCCGAGA GCAGTACCAA AAGGAGTTCA  1050
AGAACAGCAC CTACTCAAGA AGCTCAGTGG ACATGCTCTA CAGTTTTGCC  1100
AAGTGCTCGG GGTTAGACCT GATCTTTGGT CTAAATGCGT TACTACGAAC  1150
CCCAGACTTA CGGTGGAACA GcTCCAACGC CCAGCTTCTC CTTGACTACT  1200
GCTCTTCCAA GGGTTATAAC ATcTCCTGGG AACTGGGCAA TGAGCCCAAC  1250
AGTTTcTGGA AGAAAGCTCA CATTCTCATC GATGGGTTGC AGTTAGGAGA  1300
AGACTTTGTG GAGTTGCATA AACTTcTACA AAGGTCAGCT TTCCAAAATG  1350
CAAAACTCTA TGGTCCTGAC ATCGGTCAGC CTCGAGGGAA GACAGTTAAA  1400
CTGCTGAGGA GTTTCCTGAA GGCTGGCGGA GAAGTGATCG ACTCTCTTAC  1450
ATGGCATCAC TATTACTTGA ATGGACGCAT CGCTACCAAA GAAGATTTTC  1500
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TGAGCTCTGA TGCGCTGGAC ACTTTTATTC TCTCTGTGCA AAAAATTCTG 1550
AAGGTCACTA AAGAGATCAC ACCTGGCAAG AAGGTCTGGT TGGGAGAGAC 1600
GAGCTCAGCT TACGGTGGCG GTGCACCCTT GCTGTCCAAC ACCTTTGCAG 1650
CTGGCTTTAT GTGGCTGGAT AAATTGGGCC TGTCAGCCCA GATGGGCATA 1700
GAAGTCGTGA TGAGGCAGGT GTTCTTCGGA GCAGGCAACT ACCACTTAGT 1750
GGATGAAAAC TTTGAGCCTT TACCTGATTA CTGGCTCTCT CTTCTGTTCA 1800
AGAAACTGGT AGGTCCCAGG GTGTTACTGT CAAGAGTGAA AGGCCCAGAC 1850
AGGAGCAAAC TCCGAGTGTA TCTCCACTGC ACTAACGTCT ATCACCCACG 1900
ATATCAGGAA GGAGATCTAA CTCTGTATGT CCTGAACCTC CATAATGTCA 1950
CCAAGCACTT GAAGGTACCG CCTCCGTTGT TCAGGAAACC AGTGGATACG 2000
TACCTTCTGA AGCCTTCGGG GCCGGATGGA TTACTTTCCA AATCTGTCCA 2050
ACTGAACGGT CAAATTCTGA AGATGGTGGA TGAGCAGACC CTGCCAGCTT 2100
TGACAGAAAA ACCTCTCCCC GCAGGAAGTG CACTAAGCCT GCCTGCCTTT 2150
TCCTATGGTT TTTTTGTCAT AAGAAATGCC AAAATCGCTG CTTGTATATG 2200
AAAATAAAAG GCATACGGTA CCCCTGAGAC AAAAGCCGAG GGGGGTGTTA 2250
TTCATAAAAC AAAACCCTAG TTTAGGAGGC CACCTCCTTG CCGAGTTCCA 2300
GAGCTTCGGG AGGGTGGGGT ACACTTCAGT ATTACATTCA GTGTGGTGTT 2350
CTCTCTAAGA AGAATACTGC AGGTGGTGAC AGTTAATAGC ACTGTG 2396

(2) INFORMATION FOR SEQ ID NO:44:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 535
(B) TYPE: amino acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:44

Met Leu Arg Leu Leu Leu Leu Trp Leu Trp Gly Pro Leu Gly Ala
5 10 15
Leu Ala Gln Gly Ala Pro Ala Gly Thr Ala Pro Thr Asp Asp Val
20 25 30
Val Asp Leu Glu Phe Tyr Thr Lys Arg Pro Leu Arg Ser Val Ser
35 40 45
Pro Ser Phe Leu Ser Ile Thr Ile Asp Ala Ser Leu Ala Thr Asp
50 55 60
Pro Arg Phe Leu Thr Phe Leu Gly Ser Pro Arg Leu Arg Ala Leu
65 70 75
Ala Arg Gly Leu Ser Pro Ala Tyr Leu Arg Phe Gly Gly Thr Lys
80 85 90
Thr Asp Phe Leu Ile Phe Asp Pro Asp Lys Glu Pro Thr Ser Glu
95 100 105
Glu Arg Ser Tyr Trp Lys Ser Gln Val Asn His Asp Ile Cys Arg
110 115 120
Ser Glu Pro Val Ser Ala Ala Val Leu Arg Lys Leu Gln Val Glu
125 130 135
Trp Pro Phe Gln Glu Leu Leu Leu Leu Arg Glu Gln Tyr Gln Lys
140 145 150
Glu Phe Lys Asn Ser Thr Tyr Ser Arg Ser Ser Val Asp Met Leu
155 160 165
Tyr Ser Phe Ala Lys Cys Ser Gly Leu Asp Leu Ile Phe Gly Leu
170 175 180
Asn Ala Leu Leu Arg Thr Pro Asp Leu Arg Trp Asn Ser Ser Asn
185 190 195
Ala Gln Leu Leu Leu Asp Tyr Cys Ser Ser Lys Gly Tyr Asn Ile
200 205 210
Ser Trp Glu Leu Gly Asn Glu Pro Asn Ser Phe Trp Lys Lys Ala
215 220 225
His Ile Leu Ile Asp Gly Leu Gln Leu Gly Glu Asp Phe Val Glu

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                230                     235                     240
Leu His Lys Leu Leu Gln Arg Ser Ala Phe Gln Asn Ala Lys Leu
                245                     250                     255
Tyr Gly Pro Asp Ile Gly Gln Pro Arg Gly Lys Thr Val Lys Leu
                260                     265                     270
Leu Arg Ser Phe Leu Lys Ala Gly Gly Glu Val Ile Asp Ser Leu
                275                     280                     285
Thr Trp His His Tyr Tyr Leu Asn Gly Arg Ile Ala Thr Lys Glu
                290                     295                     300
Asp Phe Leu Ser Ser Asp Ala Leu Asp Thr Phe Ile Leu Ser Val
                305                     310                     315
Gln Lys Ile Leu Lys Val Thr Lys Glu Ile Thr Pro Gly Lys Lys
                320                     325                     330
Val Trp Leu Gly Glu Thr Ser Ser Ala Tyr Gly Gly Gly Ala Pro
                335                     340                     345
Leu Leu Ser Asn Thr Phe Ala Ala Gly Phe Met Trp Leu Asp Lys
                350                     355                     360
Leu Gly Leu Ser Ala Gln Met Gly Ile Glu Val Val Met Arg Gln
                365                     370                     375
Val Phe Phe Gly Ala Gly Asn Tyr His Leu Val Asp Glu Asn Phe
                380                     385                     390
Glu Pro Leu Pro Asp Tyr Trp Leu Ser Leu Leu Phe Lys Lys Leu
                395                     400                     405
Val Gly Pro Arg Val Leu Leu Ser Arg Val Lys Gly Pro Asp Arg
                410                     415                     420
Ser Lys Leu Arg Val Tyr Leu His Cys Thr Asn Val Tyr His Pro
                425                     430                     435
Arg Tyr Gln Glu Gly Asp Leu Thr Leu Tyr Val Leu Asn Leu His
                440                     445                     450
Asn Val Thr Lys His Leu Lys Val Pro Pro Pro Leu Phe Arg Lys
                455                     460                     465
Pro Val Asp Thr Tyr Leu Leu Lys Pro Ser Gly Pro Asp Gly Leu
                470                     475                     480
Leu Ser Lys Ser Val Gln Leu Asn Gly Gln Ile Leu Lys Met Val
                485                     490                     495
Asp Glu Gln Thr Leu Pro Ala Leu Thr Glu Lys Pro Leu Pro Ala
                500                     505                     510
Gly Ser Ala Leu Ser Leu Pro Ala Phe Ser Tyr Gly Phe Phe Val
                515                     520                     525
Ile Arg Asn Ala Lys Ile Ala Ala Cys Ile
                530                     535
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(2) INFORMATION FOR SEQ ID NO:45:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 2396

(B) TYPE: nucleic acid

(C) STRANDEDNESS: double

(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:45

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                                                 TT TCT AGT     8
TGC TTT TAG CCA ATG TCG GAT CAG GTT TTT CAA GCG ACA AAG AGA    53
TAC TGA GAT CCT GGG CAG AGG ACA TCC TAG CTC GGT CAG ATT TGG    98
GCA GGC TCA AGT GAC CAG TGT CTT AAG GCA GAA GGG AGT CGG GGT   143
AGG GTC TGG CTG AAC CCT CAA CCG GGG CTT TTA ACT CAG GGT CTA   188
GTC CTG GCG CCA AAT GGA TGG GAC CTA GAA AAG GTG ACA GAG TGC   233
GCA GGA CAC CAG GAA GCT GGT CCC ACC CCT GCG CGG CTC CCG GGC   278
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GCT CCC TCC CCA GGC CTC CGA GGA TCT TGG ATT CTG GCC ACC TCC 323
GCA CCC TTT GGA TGG GTG TGG ATG ATT TCA AAA GTG GAC GTG ACC 368
GCG GCG GAG GGG AAA GCC AGC ACG GAA ATG AAA GAG AGC GAG GAG 413
GGG AGG GCG GGG AGG GGA GGG CGC TAG GGA GGG ACT CCC GGG AGG 458
GGT GGG AGG GAT GGA GCG CTG TGG GAG GGT ACT GAG TCC TGG CGC 503
CAG AGG CGA AGC AGG ACC GGT TGC AGG GGG CTT GAG CCA GCG CGC 548
CGG CTG CCC CAG CTC TCC CGG CAG CGG GCG GTC CAG CCA GGT GGG 593
ATG CTG AGG CTG CTG CTG CTG TGG CTC TGG GGG CCG CTC GGT GCC 638
Met Leu Arg Leu Leu Leu Leu Trp Leu Trp Gly Pro Leu Gly Ala
5 10 15

CTG GCC CAG GGC GCC CCC GCG GGG ACC GCG CCG ACC GAC GAC GTG 683
Leu Ala Gln Gly Ala Pro Ala Gly Thr Ala Pro Thr Asp Asp Val
20 25 30

GTA GAC TTG GAG TTT TAC ACC AAG CGG CCG CTC CGA AGC GTG AGT 728
Val Asp Leu Glu Phe Tyr Thr Lys Arg Pro Leu Arg Ser Val Ser
35 40 45

CCC TCG TTC CTG TCC ATC ACC ATC GAC GCC AGC CTG GCC ACC GAC 773
Pro Ser Phe Leu Ser Ile Thr Ile Asp Ala Ser Leu Ala Thr Asp
50 55 60

CCG CGC TTC CTC ACC TTC CTG GGC TCT CCA AGG CTC CGT GCT CTG 818
Pro Arg Phe Leu Thr Phe Leu Gly Ser Pro Arg Leu Arg Ala Leu
65 70 75

GCT AGA GGC TTA TCT CCT GCA TAC TTG AGA TTT GGC GGC ACA AAG 863
Ala Arg Gly Leu Ser Pro Ala Tyr Leu Arg Phe Gly Gly Thr Lys
80 85 90

ACT GAC TTC CTT ATT TTT GAT CCG GAC AAG GAA CCG ACT TCC GAA 908
Thr Asp Phe Leu Ile Phe Asp Pro Asp Lys Glu Pro Thr Ser Glu
95 100 105

GAA AGA AGT TAC TGG AAA TCT CAA GTC AAC CAT GAT ATT TGC AGG 953
Glu Arg Ser Tyr Trp Lys Ser Gln Val Asn His Asp Ile Cys Arg
110 115 120

TCT GAG CCG GTC TCT GCT GCG GTG TTG AGG AAA CTC CAG GTG GAA 998
Ser Glu Pro Val Ser Ala Ala Val Leu Arg Lys Leu Gln Val Glu
125 130 135

TGG CCC TTC CAG GAG CTG TTG CTG CTC CGA GAG CAG TAC CAA AAG 1043
Trp Pro Phe Gln Glu Leu Leu Leu Leu Arg Glu Gln Tyr Gln Lys
140 145 150

GAG TTC AAG AAC AGC ACC TAC TCA AGA AGC TCA GTG GAC ATG CTC 1088
Glu Phe Lys Asn Ser Thr Tyr Ser Arg Ser Ser Val Asp Met Leu
155 160 165

TAC AGT TTT GCC AAG TGC TCG GGG TTA GAC CTG ATC TTT GGT CTA 1133
Tyr Ser Phe Ala Lys Cys Ser Gly Leu Asp Leu Ile Phe Gly Leu
170 175 180

AAT GCG TTA CTA CGA ACC CCA GAC TTA CGG TGG AAC AGc TCC AAC 1178
Asn Ala Leu Leu Arg Thr Pro Asp Leu Arg Trp Asn Ser Ser Asn

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                185                     190                     195

GCC CAG CTT CTC CTT GAC TAC TGC TCT TCC AAG GGT TAT AAC ATc    1223
Ala Gln Leu Leu Leu Asp Tyr Cys Ser Ser Lys Gly Tyr Asn Ile
                200                     205                     210

TCC TGG GAA CTG GGC AAT GAG CCC AAC AGT TTc TGG AAG AAA GCT    1268
Ser Trp Glu Leu Gly Asn Glu Pro Asn Ser Phe Trp Lys Lys Ala
                215                     220                     225

CAC ATT CTC ATC GAT GGG TTG CAG TTA GGA GAA GAC TTT GTG GAG    1313
His Ile Leu Ile Asp Gly Leu Gln Leu Gly Glu Asp Phe Val Glu
                230                     235                     240

TTG CAT AAA CTT cTA CAA AGG TCA GCT TTC CAA AAT GCA AAA CTC    1358
Leu His Lys Leu Leu Gln Arg Ser Ala Phe Gln Asn Ala Lys Leu
                245                     250                     255

TAT GGT CCT GAC ATC GGT CAG CCT CGA GGG AAG ACA GTT AAA CTG    1403
Tyr Gly Pro Asp Ile Gly Gln Pro Arg Gly Lys Thr Val Lys Leu
                260                     265                     270

CTG AGG AGT TTC CTG AAG GCT GGC GGA GAA GTG ATC GAC TCT CTT    1448
Leu Arg Ser Phe Leu Lys Ala Gly Gly Glu Val Ile Asp Ser Leu
                275                     280                     285

ACA TGG CAT CAC TAT TAC TTG AAT GGA CGC ATC GCT ACC AAA GAA    1493
Thr Trp His His Tyr Tyr Leu Asn Gly Arg Ile Ala Thr Lys Glu
                290                     295                     300

GAT TTT CTG AGC TCT GAT GCG CTG GAC ACT TTT ATT CTC TCT GTG    1538
Asp Phe Leu Ser Ser Asp Ala Leu Asp Thr Phe Ile Leu Ser Val
                305                     310                     315

CAA AAA ATT CTG AAG GTC ACT AAA GAG ATC ACA CCT GGC AAG AAG    1583
Gln Lys Ile Leu Lys Val Thr Lys Glu Ile Thr Pro Gly Lys Lys
                320                     325                     330

GTC TGG TTG GGA GAG ACG AGC TCA GCT TAC GGT GGC GGT GCA CCC    1628
Val Trp Leu Gly Glu Thr Ser Ser Ala Tyr Gly Gly Gly Ala Pro
                335                     340                     345

TTG CTG TCC AAC ACC TTT GCA GCT GGC TTT ATG TGG CTG GAT AAA    1673
Leu Leu Ser Asn Thr Phe Ala Ala Gly Phe Met Trp Leu Asp Lys
                350                     355                     360

TTG GGC CTG TCA GCC CAG ATG GGC ATA GAA GTC GTG ATG AGG CAG    1718
Leu Gly Leu Ser Ala Gln Met Gly Ile Glu Val Val Met Arg Gln
                365                     370                     375

GTG TTC TTC GGA GCA GGC AAC TAC CAC TTA GTG GAT GAA AAC TTT    1763
Val Phe Phe Gly Ala Gly Asn Tyr His Leu Val Asp Glu Asn Phe
                380                     385                     390

GAG CCT TTA CCT GAT TAC TGG CTC TCT CTT CTG TTC AAG AAA CTG    1808
Glu Pro Leu Pro Asp Tyr Trp Leu Ser Leu Leu Phe Lys Lys Leu
                395                     400                     405
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GTA GGT CCC AGG GTG TTA CTG TCA AGA GTG AAA GGC CCA GAC AGG   1853
Val Gly Pro Arg Val Leu Leu Ser Arg Val Lys Gly Pro Asp Arg
            410                 415                 420

AGC AAA CTC CGA GTG TAT CTC CAC TGC ACT AAC GTC TAT CAC CCA   1898
Ser Lys Leu Arg Val Tyr Leu His Cys Thr Asn Val Tyr His Pro
            425                 430                 435

CGA TAT CAG GAA GGA GAT CTA ACT CTG TAT GTC CTG AAC CTC CAT   1943
Arg Tyr Gln Glu Gly Asp Leu Thr Leu Tyr Val Leu Asn Leu His
            440                 445                 450

AAT GTC ACC AAG CAC TTG AAG GTA CCG CCT CCG TTG TTC AGG AAA   1988
Asn Val Thr Lys His Leu Lys Val Pro Pro Pro Leu Phe Arg Lys
            455                 460                 465

CCA GTG GAT ACG TAC CTT CTG AAG CCT TCG GGG CCG GAT GGA TTA   2033
Pro Val Asp Thr Tyr Leu Leu Lys Pro Ser Gly Pro Asp Gly Leu
            470                 475                 480

CTT TCC AAA TCT GTC CAA CTG AAC GGT CAA ATT CTG AAG ATG GTG   2078
Leu Ser Lys Ser Val Gln Leu Asn Gly Gln Ile Leu Lys Met Val
            485                 490                 495

GAT GAG CAG ACC CTG CCA GCT TTG ACA GAA AAA CCT CTC CCC GCA   2123
Asp Glu Gln Thr Leu Pro Ala Leu Thr Glu Lys Pro Leu Pro Ala
            500                 505                 510

GGA AGT GCA CTA AGC CTG CCT GCC TTT TCC TAT GGT TTT TTT GTC   2168
Gly Ser Ala Leu Ser Leu Pro Ala Phe Ser Tyr Gly Phe Phe Val
            515                 520                 525

ATA AGA AAT GCC AAA ATC GCT GCT TGT ATA TGA AAA TAA AAG GCA   2213
Ile Arg Asn Ala Lys Ile Ala Ala Cys Ile
            530                 535

TAC GGT ACC CCT GAG ACA AAA GCC GAG GGG GGT GTT ATT CAT AAA   2258
ACA AAA CCC TAG TTT AGG AGG CCA CCT CCT TGC CGA GTT CCA GAG   2303
CTT CGG GAG GGT GGG GTA CAC TTC AGT ATT ACA TTC AGT GTG GTG   2348
TTC TCT CTA AGA AGA ATA CTG CAG GTG GTG ACA GTT AAT AGC ACT   2393
GTG                                                           2396
```

(2) INFORMATION FOR SEQ ID NO:46:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 385
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:46

```
CGGCCGCTGC TGCTGCTGTG GCTCTGGGGG CGGCTCCGTG CCCTGACCCA    50
AGGCACTCCG GCGGGGACCG CGCCGACCAA AGACGTGGTG GACTTGGAGT   100
TTTACACCAA GAGGCTATTC CAAAGCGTGA GTCCCTCGTT CCTGTCCATC   150
ACCATCGACG CCAGTCTGGC CACCGACCCT CGGTTCCTCA CCTTCCTGAG   200
CTCTCCACGG CTTCGAGCCC TGTCTAGAGG CTTATCTCCT GCGTACTTGA   250
GATTTGGCGG CACCAAGACT GACTTCCTTA TTTTTGATCC CAACAACGAA   300
CCCACCTCTG AAGAAAGAAG TTACTGGCAA TCTCAAGACA ACAATGATAT   350
```

TTGCGGGTCT GACCGGGTCT CCGCTGACGT GTTGA 385

(2) INFORMATION FOR SEQ ID NO:47:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 541

(B) TYPE: nucleic acid

(C) STRANDEDNESS: double

(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:47

```
AAATCAGGAC ATATCCTTCA CTTATTTGCC TCTTGGTCAT ATTGGAGGCA   50
TTTGTATTCA TTTTTAATAA CCCTCAAAAT AGTGCATGCA AAGTGCTAAG  100
CGTCATTTGC CACATGGTGC CATTAACTGT CACCACCTGC AGTGGTCTAC  150
TTAGAGAACA CCGCACTGGA TGTTAACACT GAAGCGCGTG CCCCGCCCTC  200
CCGAGGCTCT GGATCCAGCG TTGAAGCTTG CCCCGCCCTC CCGAGGCTCT  250
GGATCCAGCA CTGGAGCATG CCCCGCCCTC CCGAGGCTCT GGAGCTTGCT  300
AAGGAGTCCG CTCCCTACCG CTGGGGTTTT GCTTTATTCT TATGAATGAC  350
ACCCCTGACC GCTTTCGTCT CAGGGGTACT GTAATGCCTT TTATTTTCAT  400
ATACAAGCTG CGATTTTGGC ATTTCTTATG ACAAAAAACC CATAGGAAAA  450
GGCGGGCACG CTTAGTGAGC TTCCTGCGGG GAGAGGTTTT TCTGTTAGAG  500
CTGGCANGGT CTGCTCATCG ACCATCTTCA GGCCTCGTGC C           541
```

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/03542

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) :C12N 15/56, 15/63, 1/21, 9/24, 15/11
US CL :536/23.1, 23.2; 435/200, 325, 252.3, 320.1; 424/94.61
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 536/23.1, 23.2; 435/200, 325, 252.3, 320.1; 424/94.61

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EAST, MEDLINE, BIOSIS, CAPLUS, SCISEARCH, EMBASE, JAPIO, PATOWEP, PATOSWO search terms: heparanase, gene or sequence

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X - Y	US 5,362,641 A (FUKS et al.) 08 November 1994, see entire document.	21-25 ---- 1-20, 26-28
X, P	US 5,968,822 A (PECKER et al.) 19 October 1999, see entire document.	1-28
X - Y	WO 95/04158 A1 (THE UPJOHN COMPANY) 09 Febuary 1995, see entire document.	21-25 ---- 1-24, 26-28
X, P	WO 99/11798 A1 (INSIGHT STRATEGY & MARKETING LTD.) 11 March 1999, see entire document.	1-28

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 JUNE 2000	24 JUL 2000

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/03542

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Please See Extra Sheet.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☒ No protest accompanied the payment of additional search fees.

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING
This ISA found multiple inventions as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees must be paid.

Group I, claim(s)1-7, 19, 20 and 28, drawn to a nucleic acid encoding a polypeptide having heparanase activity.
Group II, claim(s) 8-18, drawn to antisense oligonucleotides of a polynucleotide which encodes a polypeptide having heparanase activity.
Group III, claim(s) 21-25, drawn to polypeptide having heparanase activity.
Group IV, claim(s)26, drawn to a method of identifying a chromosome region harboring a heparanase gene.
Group V, claim(s) 27, drawn to a method of eliciting anti-heparanase antibodies in vivo.

The species listed above do not relate to a single inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, the species lack the same or corresponding special technical features for the following reasons: The listed inventions share a technical relationship of a polypeptide having heparanase activity, but this does not constitute a special technical feature because Fuks et al. (Fuks et al. US Patent No: 5,362,641) teach a polypeptide having heparanase activity.